Asset Sustainability Index:
A Proposed Measure for Long-Term Performance

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16. Abstract

This report examines the concept of asset sustainability metrics. Such metrics address the long-term performance of highway assets based upon expected expenditure levels. It examines how such metrics are used in Australia, Britain and the private sector. It also reviews asset management data from selected states to illustrate that long-term sustainability metrics could be produced using available US asset management data.

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Forward

The FHWA, through the Office of Planning, Environment, and Realty solicited for research and development projects that could lead to transformational changes and revolutionary advances for transportation planning in the United States. This report, *Asset Sustainability Index: A Proposed Measure for Long Term Performance,* is a product of that research.

This report examines the use of forward-looking metrics in Australia, Great Britain and in the private sector that measure the sustainability of infrastructure conditions. These metrics encourage a long-term, asset-management-based approach to managing infrastructure, not just to meet condition targets today, but to sustain those targets into the future.

The report also examines the asset management data and systems used in four US states to determine if they could produce long-term sustainability metrics. The report demonstrates that US agencies that have mature asset management systems can produce long-term metrics that provide insight into the future condition of transportation assets. Thus, sustainability metrics such as those used in Australia can be produced in the US using available asset management systems.

The report is intended to provide the transportation community with additional perspectives on performance management as it considers how to integrate accountability, performance, and sustainability into US transportation programs. Most performance measurement systems focus upon current performance. However, the long-term performance of infrastructure is based upon long-term strategies, such as preventive maintenance, which may not significantly increase performance immediately. Adding to the suite of performance metrics some that examine long-term performance can help decision makers understand how today's actions can influence transportation performance in the next decade. The forward-looking perspective embraces sustainability and allows the current generation of decision makers to understand how their actions will affect a future generation of transportation users.

Executive Summary

This report examines the concept of a suite of proposed performance measures centered around an Asset Sustainability Index (ASI). The metrics are proposed to be inherently forward looking and to address a fundamental question surrounding infrastructure management. That is, will current actions result in a financially sustainable highway system? Or, will current actions come at the expense of future stakeholders who will inherit a deteriorated and depreciated highway network?

The metrics are examined primarily for State transportation agency officials but they could be useful to all who manage transportation networks be they at the national, State, regional or local level. Increasingly, these officials are expected to demonstrate they are operating responsibly and transparently. In addition, they face concerns over sustainability. The proposed suite of financial sustainability metrics allow them to add to their performance reporting a set of measures that are forward-looking, leading measures that help predict the future consequences of today's investment decisions.

Performance measures help to allocate resources, make difficult tradeoffs and to demonstrate accountability. Their use among State transportation agencies is relatively new, having gained prominence in the past decade. Performance measurement in the private sector and in the international transportation sector is more mature, and its lessons hold implications for U.S. transportation officials. A review of the private-sector evolution of performance measures illustrates that over time managers came to increasingly rely upon leading measures, as opposed to backward-looking or lagging measures. Leading measures illustrate the likely consequences of today's actions on future conditions. Lagging measures are inherently backward looking and provide only inferences into future results.

Mature performance-measurement frameworks such as the Triple Bottom Line or the Balanced Scorecard often emphasize forward-looking or leading indicators. They use leading indicators to forecast whether today's actions are likely to achieve the desired results for future stakeholders, or are today's actions coming at the expense of those future stakeholders?

The financial sustainability metrics in this report build off of similar metrics in Great Britain, Australia and the private sector that measure whether current investment levels will sustain future condition targets. As noted in a Queensland, Australia, sustainability act, *"A local government is **financially sustainable** if the local government is able to maintain its financial capital and infrastructure capital over the long term."* The Asset Sustainability Index and its related measures look forward to assess whether the infrastructure investment allows sustainable conditions into the future, preferably for a time horizon of at least 10 years.

Federal, State and local transportation officials repeatedly stress their concern over the condition of their transportation assets and whether they can sustain them at an acceptable condition into the future. Their concerns over future infrastructure sustainability mirrors other national areas of concern. The deficits growing in the Federal budget, Social Security and Medicare create serious national debates about the sustainability of these important programs. However, continuing underinvestment in infrastructure also is creating an "infrastructure deficit." If investment is inadequate, current users are consuming infrastructure that they are not replenishing for future generations. Today's users are, in effect, consuming the infrastructure of their children. This report examines asset sustainability metrics that can illustrate if current users are leaving a legacy for future users, or creating a deficit for them.

This Asset Sustainability Index as proposed in this report is a ratio of the amount budgeted for highway infrastructure preservation divided by the amount needed to adequately sustain infrastructure at a targeted condition over the long term.

$$\frac{\textbf{Amount Budgeted}}{\textbf{Amount Needed}} = \textbf{Asset Sustainability Index}$$

As seen in figure 1, this report examines the proposed index as a composite of three ratios, a Pavement Sustainability Ratio, a Bridge Sustainability Ratio and a Maintenance Sustainability Ratio. When combined, they form an Asset Sustainability Index which is a composite of all three. Aggregated, the Asset Sustainability Index provides at-a-glance summation of critical investment trends. Disaggregated, it allows "drilling down" into system-level or asset-level sustainability.

Although the index and ratios are considered to be simple in concept, the Asset Sustainability Index can be an informative metric useful for long-range plans, short-term State Transportation Improvement Programs or for public budgeting decisions particularly when tracked over time. They boil down complex, long-term infrastructure condition and investment analysis into a suite of easy-to-illustrate metrics. The insight they provide increases with the length of the analysis period.

As this report points out, missing among U.S. transportation practice is a common framework for determining the needed investment to sustain infrastructure at an acceptable condition. The ASI is Need divided by Budget but there is not a common process for identifying the needed investment for a highway network. To create an analogy, there is no Highway Capacity Manual for infrastructure condition. The Highway Capacity Manual creates a national standard for measuring and setting acceptable levels of highway capacity performance. It defines levels of service as A through F and creates volume-to-capacity ratios for various types of highways. These metrics are universally understood among highway practitioners in the United States and in many nations abroad. The HCM even includes a forecasting component with standards set to ensure adequate levels of service into the future, generally 20 years.

No analogous process exists for universally measuring and forecasting the condition of a highway network and the needed investment to sustain it. The product of such an analysis could be considered to produce a Transportation Asset Management Plan that indicates what comprehensive series of investments are necessary to sustain asset conditions for a forecasted period, say 10 or 20 years. If such a plan were based on Transportation Asset Management principles, it would be policy driven and include a comprehensive mix of treatments to ensure the lowest lifecycle costs for the various highway assets. Throughout this report, case studies illustrate that sustainability metrics can be generated in the U.S. . However, in each case study, no actual Transportation Asset Management plan exists. Instead, the analysis "teases out" from the mature asset management practices of the examined States how their asset management practices produce credible estimates of "need" that resemble what a mature Transportation Asset Management Plan would include.

This report also borrows from the private sector. The ASI and its components are analogous to the capital-investment metrics financial analysts use to evaluate the long-term health of capital-intensive companies such as manufacturers, railroads or electric utilities. If capital-intensive industries fail to adequately invest in their own capital assets, they are considered by analysts to be poor long-term investments. In effect, current owners are consuming the physical assets that future shareholders need.

Building from international examples, the ASI emulates recent practices in Great Britain and Australia in which State and local governments are required to report on the long-term financial sustainability of their infrastructure. State and local governments are required to demonstrate they are not under-investing in infrastructure and creating future unfunded maintenance and repair needs, such as illustrated in Figure 2. Figure 2 illustrates that levels budgeted for sustaining highway infrastructure conditions were near needed levels in this example in the early 2000s but began to decline relative to need. As assets aged, their condition deteriorated at a more rapid rate, needed investments rose and the relatively modest budget increases consistently fell behind the needed investment. The Asset Sustainability Index fell over

20 years from a high of .97 to .53. In other words, in this forecast by 2019 if these trends continue only 53 percent of the investment needed to sustain highway infrastructure conditions will be budgeted. In Figure 2, the mid-point of the 20-year trend is highlighted to illustrate for policy makers the past trends and likely future consequences of the current forecasts.

Generating the Asset Sustainability Index relies on two credible forecasts. One is for the amount of needed investment, preferably developed from a credible Transportation Asset Management analysis. The second element is a long-term fiscal forecast. Although complex, these two analyses are produced by capital-intensive private-sector corporations and are being developed by State and local governments in Australia and on an ad hoc basis by the U.S. agencies examined in this report.

This report describes the ASI and examines whether it can be produced using typically available U.S. highway data.

The report also explores a complementary set of metrics, those related to "Asset Valuation." Asset valuation is defined as the calculated monetary value of an asset or class of assets. By tracking over the long-term whether a transportation agency's assets are increasing or declining in value, the effect of investment also can be displayed. If asset values decline, society is losing its highway equity and not replenishing that equity for future users. In Australia, Great Britain and in the private sector Asset Valuation serves as a complementary metric to those such as the Asset Sustainability Index. They seek to determine whether current actions increase or decrease "public equity."

The report is organized in the following manner:

Chapter 1 defines and describes an Asset Sustainability Index, which is comprised of three metrics or ratios. It will include brief illustrating examples.

Chapter 2 will describe private sector precedents for an ASI and how such asset-investment ratios are considered to be a basic form of accountability among publicly traded companies, particularly railroads.

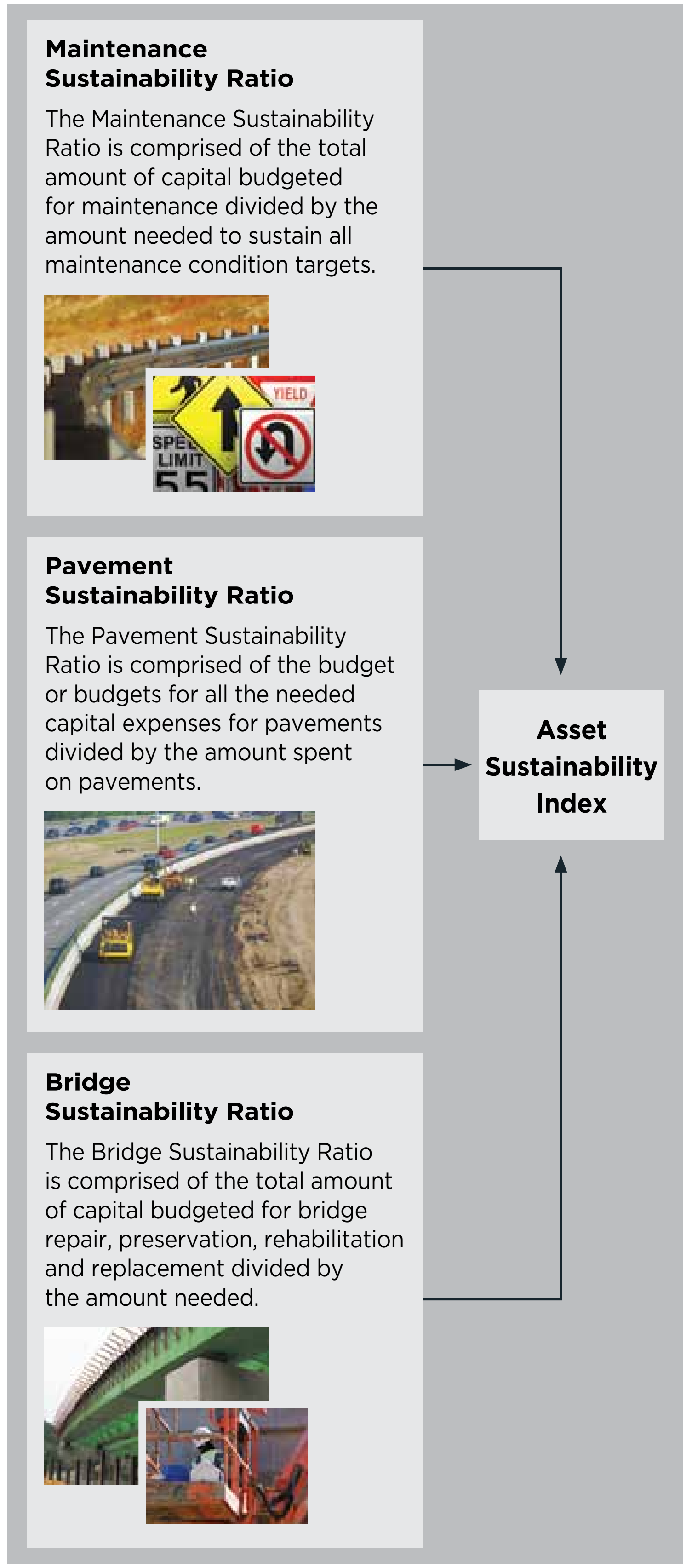
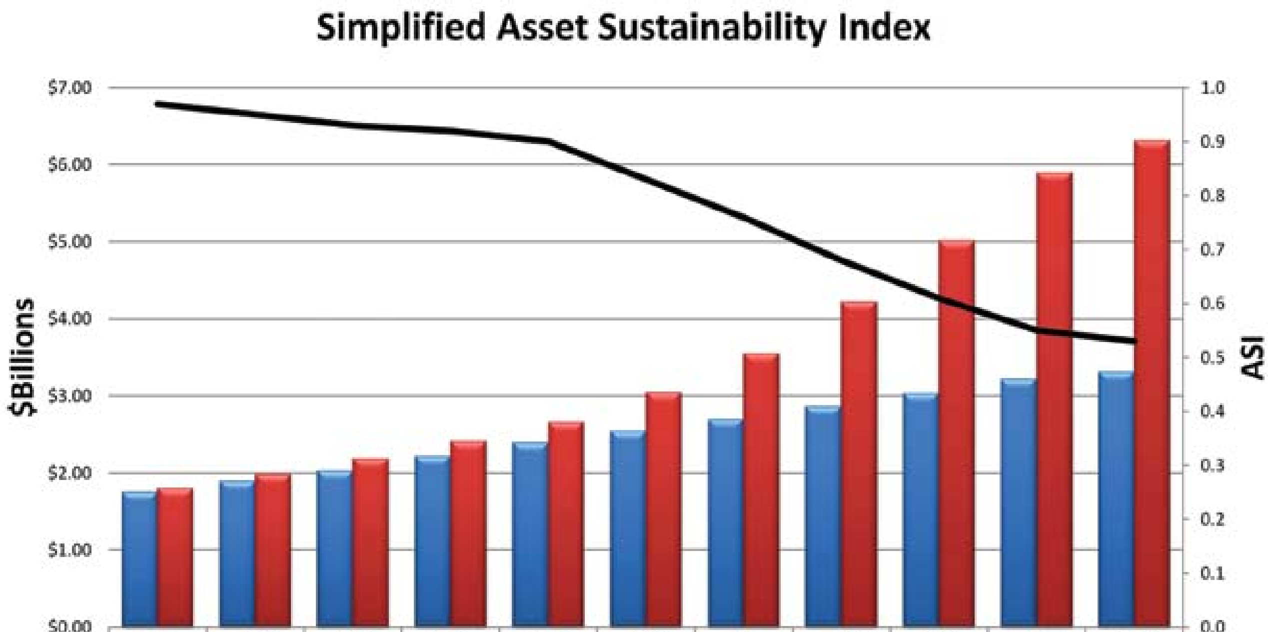


Figure 1. *Ratios from Maintenance, Pavements and Bridges combine into the Asset Sustainability Index.*



	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2019
Budget	$1.75	$1.89	$2.03	$2.21	$2.39	$2.54	$2.70	$2.86	$3.03	$3.22	$3.31
Need	$1.80	$1.98	$2.19	$2.41	$2.66	$3.04	$3.55	$4.22	$5.01	$5.90	$6.31
ASI	0.97	0.95	0.93	0.92	0.90	0.83	0.76	0.68	0.61	0.55	0.53

Budget Need ASI

Figure 2. *This illustration depicts how the use of the ASI in a time series represents an important decline in needed infrastructure investment.*

Chapter 3 provides international precedents to the ASI, including ones from Australia and Great Britain. Both countries are recognized leaders in Transportation Asset Management and performance measurement. Both adopted metrics similar to an ASI in recent years.

Chapter 4 examines how data from example States were tapped to illustrate a Pavement Sustainability Ratio.

Chapter 5 illustrates a Bridge Sustainability Ratio using existing condition and expenditure data from States.

Chapter 6 illustrates a Maintenance Sustainability Ratio, again based on existing State condition and expenditure data.

Chapter 7 illustrates how the three ratios for Pavement, Bridges and Maintenance can be compiled into a comprehensive highway Asset Sustainability Index.

Chapter 8 reviews the Governmental Accounting Standards Board Statement No. 34 (GASB 34) requirements and discusses the related concept of Asset Valuation. Asset Valuation analysis tracks the value of infrastructure over time to determine whether investment is sufficient to offset depreciation or deterioration. By treating highway assets as "equity" the highway agency can evaluate whether it is increasing the public's equity, or decreasing it. This section relies heavily upon the GASB 34 reports and underlying concepts.

Chapter 9 discusses three ways in which agencies can generate an ASI. The first is by using the analysis from the TAM systems. The second is to use inventory condition data over time. The third means is to use a general depreciation exercise, similar to the depreciation method of accounting for GASB 34. In all three cases, agency expenditures are compared to needed investment.

Chapter 10 offers summary, concluding remarks and considerations for next steps.

CHAPTER 1

The Asset Sustainability Index

State transportation officials have long experience in measuring infrastructure condition. They produce extensive inventories of bridges, pavements, and roadside assets and they have tracked their condition over time. In cases where mature management systems are in place, the highway officials often create forecasts and scenarios to evaluate different investment options.

The Asset Sustainability Index concept allows transportation officials to portray their infrastructure condition information in additional ways to communicate more effectively about the consequences of current trends. By its very nature, highway infrastructure is a long-term asset whose future condition is dependent upon long-term actions. A long-term perspective is even more important when an entire network or system of assets is being evaluated.

In concept, the Asset Sustainability Index should be simple to grasp. As seen in Figure 1, it is a calculation of need divided by budget for various highway infrastructure categories. For the purposes of this report, it will be defined as:

An Asset Sustainability Index is a composite metric computed by dividing the amount budgeted on infrastructure maintenance and preservation over time by the amount needed to achieve a specific infrastructure condition target.

Stated mathematically, it is:

$$\frac{\text{Amount Budgeted}}{\text{Amount Needed}} = \text{Asset Sustainability Index}$$

In the definition, the terms "maintenance" and "preservation" are used generically to include all preventive, reactive, rehabilitative and even replacement activities that contribute to the achievement of an infrastructure condition target.

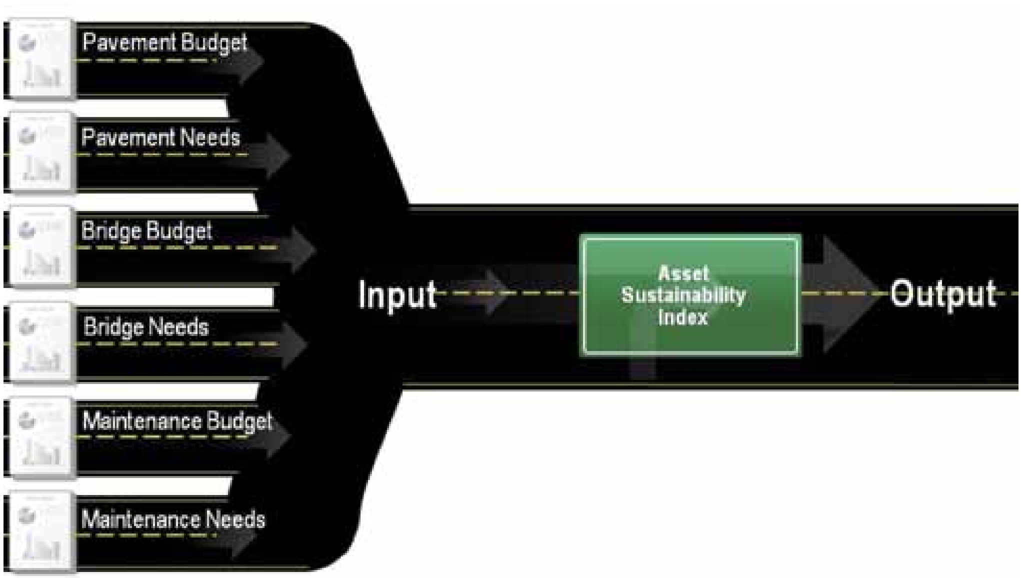


Figure 3. *Inputs to the Asset Sustainability Index.*

The terms "maintenance" and "preservation" are not intended to be synonymous with any terms relating to eligibility of Federal Highway Administration or other funds. The index also relies on "budgeted" not "spent" or "obligated" funds. The index is a planning and long-term programming metric. As such it assumes a high correlation exists between the amount budgeted for a program and the amount actually spent over time. Although the amount budgeted for a program and the amount spent for it may vary year to year, over time a strong correlation is assumed for the ASI. A separate discussion regarding inordinately costly items, such as rehabilitation of major bridges or pavements, is addressed later. Also addressed later in this chapter is a discussion of how to capture "need" in a credible and replicable way.

An ASI of 1.0 is considered optimum because expenditures match need. Economically, a perfect match of need and expenditure is most efficient because it preserves infrastructure for the lowest cost over time and excess spending above 1.0 can be redirected to other needs. The budgeted amount is the numerator and the need the denominator to allow the representation of 1.0 to be optimum. Any fractional number below 1.0 illustrates a deficit in investment and a number above 1.0 illustrates excess spending. "Excess" however, may be needed temporarily to eliminate backlogs in deficiencies. Again, as the ASI is intended to be a long-term, planning metric the optimum amount of investment is that which is needed to sustain conditions at a targeted level over the long-term.

Webster's Third New International Dictionary defines an index as, "a ratio or other number derived from a series of observations and used as an indicator or measure." The ASI is proposed to be used in a time series to measure trends. The time series is deemed to be important because of the long-term nature of infrastructure management and performance.

As an index, the ASI is proposed to summarize or comprise three ratios, a Pavement Sustainability Ratio, a Bridge Sustainability Ratio and a Maintenance Sustainability Ratio. They will have nearly identical definitions which are:

A Pavement Sustainability Ratio is a metric calculated by dividing the amount budgeted for pavement maintenance and preservation over time by the amount needed to achieve a specific pavement condition target.

$$\frac{\text{Pavement Budget}}{\text{Pavement Needs}} = \text{Pavement Sustainability Ratio}$$

A Bridge Sustainability Ratio is a metric calculated by dividing the amount budgeted for bridge maintenance and preservation over time by the amount needed to achieve a specific bridge condition target.

$$\frac{\text{Bridge Budget}}{\text{Bridge Needs}} = \text{Bridge Sustainability Ratio}$$

A Maintenance Sustainability Ratio is a metric calculated by dividing the amount budgeted for roadway maintenance needs over time by the amount needed to achieve a specific roadway maintenance appurtenance condition target. The ratio addresses capital expenditures, and can include labor and equipment costs depending upon the user's practices.

$$\frac{\text{Maintenance Capital Budget}}{\text{Maintenance Capital Need}} = \text{Maintencance Sustainability Ratio}$$

The capital items included in a Maintenance Sustainability Ratio could vary depending upon the definitions used by the highway agency. At the simplest level, they would include capital expenditures for guardrail, pavement markings, and signs. Depending upon the accounting and program practices of a department, it could include traffic signals, culverts, drainage items or other items. In the North Carolina DOT case study the definition of maintenance is much broader and extends to bridge and pavement items as well. For simplicity in this report, generally the capital items of guardrail, pavement markings and signs are included although that varies depending upon the available State data used in the examples. If a department desired, the necessary expenditures for labor and equipment also could be included. For instance, if it calculated that a given amount of labor, equipment and capital was necessary to sustain guardrail at a given targeted level, those three expenditure inputs could be used in the numerator and denominator for a Guardrail Sustainability Ratio. That ratio could be incorporated into the larger Maintenance Sustainability Ratio.

Generically, any of the three ratios could be called Asset Sustainability Ratios. The definition for an Asset Sustainability Ratio would be:

An Asset Sustainability Ratio is any asset-class-specific ratio of budget divided by the amounted needed to sustain condition targets over the long-term and could refer generically to the Pavement Sustainability Ratio, the Bridge Sustainability Ratio or the Maintenance Sustainability Ratio.

A simple example of a Pavement Sustainability Ratio follows. A highway agency calculates from its pavement management process that a rational annualized program of preventive, reactive, rehabilitative and replacement projects necessary to sustain its rural highway system pavement conditions is $200 million annually. It divided the amount it budgets for rural system pavements by $200 million to calculate 1 year's PSR for rural pavements. As seen in Table 1 the amount budgeted and the amount needed in 2000 both are $200 million, therefore, the PSR is 1.0.

The agency has balanced its expenditures and needs for rural pavements. As a result, for that year its rural pavements are sustainable. However, as the last column of Table 1 indicates, the highway agency increased rural pavement expenditures by 3 percent annually, but inflation created 4 percent annual growth rate in costs. Need by 2004 grew to $234 million but budgets were only $225 million. Commensurately, the PSR fell to .96

For budgeters, planners, programmers, legislators and similar parties interested in the long-term stability of the highway network, the PSR provides a relative, proportional indicator of the gap between need and investment for the pavement network. To add further relevance, additional metrics that are key inputs to or from the PSR can be included in the reporting process to provide additional insight. In 2000, the rural highway network was valued at $3.5 billion, gradually declining to $3.328 billion by 2004. In other words, this pattern of investment led to the State losing $172 million in "equity." The taxpayers owned $3.5 billion worth of rural highway assets in 2000 but the value of those assets declined to $3.328 billion in only five years as the pavements degraded and were not adequately repaired. The ability of the Pavement Sustainability Ratio and the Asset Valuation to illustrate the consequences of underinvestment increases with the time series.

In Figure 4 (see next page), the long-term consequences of what appears to be a relatively minor amount of under-investment each year become clearer. From 2000 through 2010 the PSR for rural highway system pavements only gradually declined from 1.0 to .91. Superficially, it appears that based on the PSR, that investment was only 9 percent below optimum. However, over time that led to a steady decline in asset valuation. The rural highway system began with a value of $3.5 billion, declined to $2.887 billion by 2011 and is forecast to fall to $1.762 billion by 2019. Over the course of 20 years, the value of the highway agency's rural pavement assets declined by 50 percent. This leaves future users with much less "equity", lower pavement conditions and a substantial backlog in investment required to restore the asset's value and functionality.

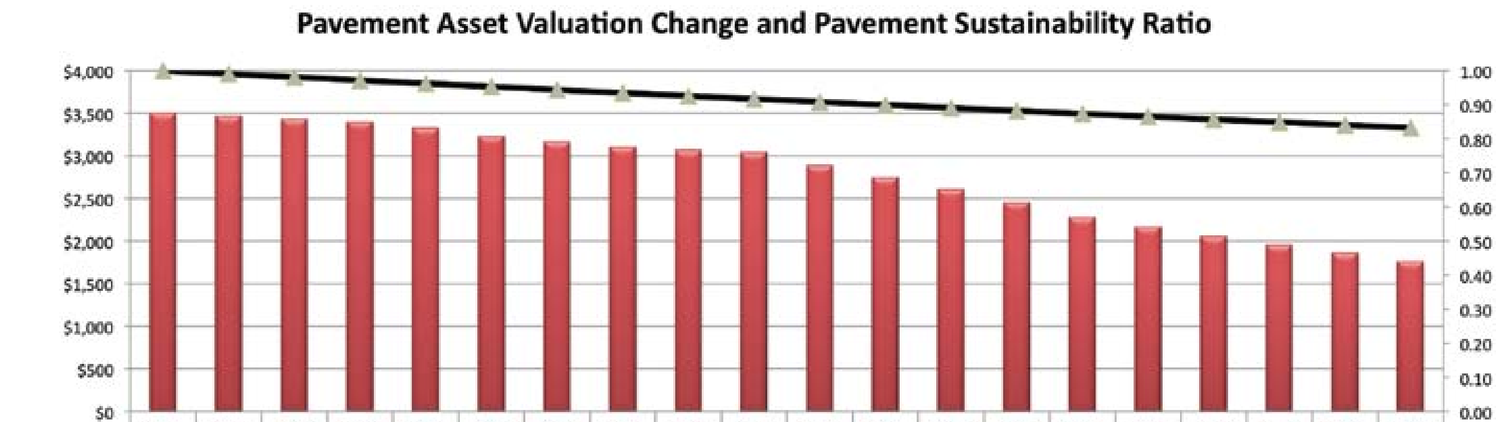
A ratio such as the PSR is intended to help budgeters "calibrate" a highway agency's

Table 1. *Pavement Sustainability Ratio*

	2000	2001	2002	2003	2004	Rate of Growth
Budgeted	$200	$206	$212	$219	$225	3%
Needed	$200	$208	$216	$225	$234	4%
PSR	1.0	.99	.98	.97	.96	

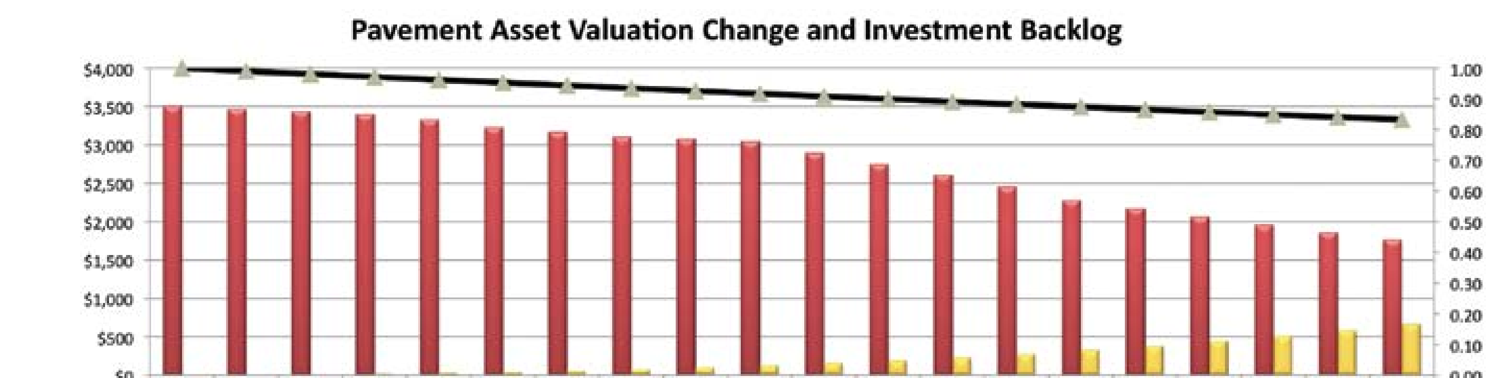
Table 2. *Asset value and annual investment needs*

	2000	2001	2002	2003	2004	Annual Rate of Change
Budgeted	$200	$206	$212	$219	$225	3%
Needed	$200	$208	$216	$225	$234	4%
PSR	1.0	0.99	0.98	0.97	0.96	1.0%
Asset Valuation	$3500	$3,465	$3,430	$3,396	$3,328	5%



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Asset Valuation	$3,500	$3,465	$3,430	$3,396	$3,328	$3,228	$3,164	$3,100	$3,069	$3,039	$2,887	$2,742	$2,605	$2,449	$2,278	$2,164	$2,056	$1,953	$1,855	$1,762
PSR	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.83

Figure 4. *Pavement Sustainability Ratio and valuation over time.*



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Asset Valuation	$3,500	$3,465	$3,430	$3,396	$3,328	$3,228	$3,164	$3,100	$3,069	$3,039	$2,887	$2,742	$2,605	$2,449	$2,278	$2,164	$2,056	$1,953	$1,855	$1,762
Investment Backlog	$0	$2	$7	$14	$24	$37	$53	$73	$96	$123	$154	$189	$229	$274	$323	$378	$439	$506	$580	$660
PSR	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.83

Figure 5. *The "Sustainability Gap" or investment gap.*

program. It allows budgeters to depict the amount of additional spending needed to achieve a specific condition target. Metrics such as average pavement condition, or miles of deficient pavements provide insight into the physical magnitude of pavement deficiencies. The PSR and its ASI help budgeters understand the financial magnitude of the "investment gap" or "investment surplus." As importantly, the sustainability metrics provide a simple way to communicate the adequacy of investment into a simple ratio. While concepts such as Remaining Service Life or Pavement Serviceability Index may be hard to communicate to a lay audience, the sustainability metrics are intended to provide simple ratios that indicate the degree to which investment is adequate or inadequate.

The fiscal component allows the PSR to support "triple bottom line" or "balanced scorecard" types of measurement systems. In the triple bottom line or balanced scorecard systems, multiple societal objectives are weighed. These can include environmental sustainability, infrastructure sustainability as well as financial sustainability. The PSR and ASI can feed into these types of mature performance measurement systems and can provide a financial order-of-magnitude perspective lacking from measures that only report upon infrastructure conditions, such as the Pavement Serviceability Index or International Roughness Index. The PSR or ASI is not proposed to replace those metrics, but rather to complement them.

By placing a monetary value on infrastructure through asset valuation, the under-investment in that infrastructure over time can be expressed as a loss of value to the society as a whole and as a "backlog" or "infrastructure deficit." As seen in Figure 5, the 20-year decline in PSR for this theoretical rural highway pavement inventory leads to a halving of the inventory's value and a backlog of repairs of $660 million by 2020. Although theoretical, the inputs to this analysis are based upon inventory size, average treatment costs and asset values taken from later case studies referenced in this report. In this example, they are simplified for the purposes of illustrating the PSR and asset valuation concept.

The "backlog" or "infrastructure deficit" is an intentional focus of the sustainability metrics and asset valuation efforts. They are intended to focus attention upon the future or long-term consequences of underinvestment. They allow an organization to depict to policy makers whether current investment levels lead to sustainable infrastructure for future users. Just as greater expenditures than contributions create deficits in the Social Security or Medicare programs, continued underinvestment in infrastructure creates deficits that are not normally captured in traditional highway metrics. In the theoretical case study of Figure 5, a deficit of $660 million is accumulated. To address it, the highway agency must either accept lower condition standards or it must impose upon future users substantially higher costs.

The geometric progression of miles of deficiencies, the loss of asset value and the increase in backlog are attributable to the non-linear progression of pavement degradation once pavements deteriorate to a certain point.

Figure 6 at right from the Federal Highway Administration's Office of Asset Management, Pavements and Construction illustrates the steep deterioration curve commonly seen in pavements once they reach a "poor" condition. Timely preventive and reactive treatments create substantial value by restoring pavements to a high condition and preventing the onset of the rapid deterioration commonly seen in poorly maintained pavements. As noted in Figure 6 and in other FHWA reports, timely preventive and reactive treatments can produce a very high benefit/cost ratio. Conversely, underinvestment leads to the missing of the optimal treatment-timing window for many pavements and leads to their concurrent rapid, non-linear degradation. It is the accelerating, non-linear degradation that underlies the analysis' rapid accumulation of deficient lane miles and the rapid growth in the cost of the backlog, or the accumulation of the "infrastructure deficit."

Another example of how an investment ratio can be calculated follows. This one is for guardrail, which is one component of the Maintenance Sustainability Ratio. Following this example, the "rolling up" of these individual ratios into an Asset Sustainability Index will be presented.

Figure 7 (see next page) illustrates how a guardrail Sustainability Ratio would work. The blue bars and accompanying data table illustrate amounts budgeted for guardrail for a hypothetical highway agency. The red bars illustrate the needed level of investment to achieve the target. For instance in 2000, $10 million is needed but only $8 million is

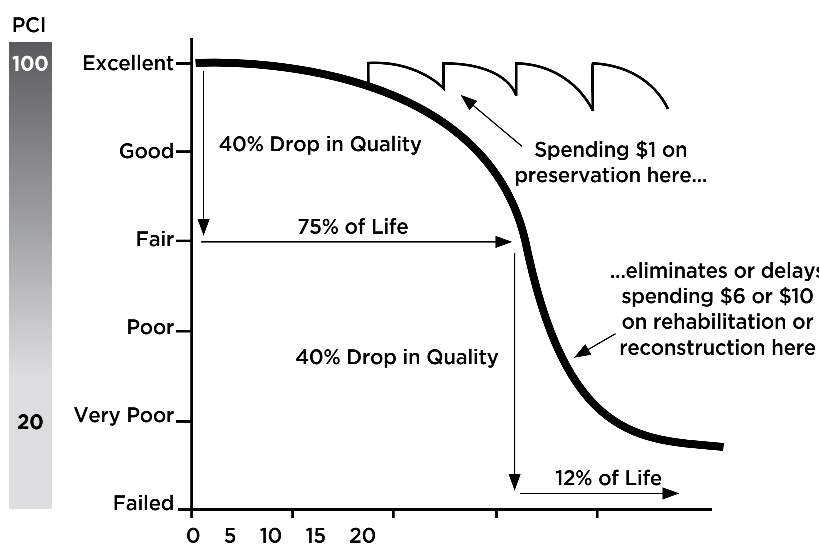
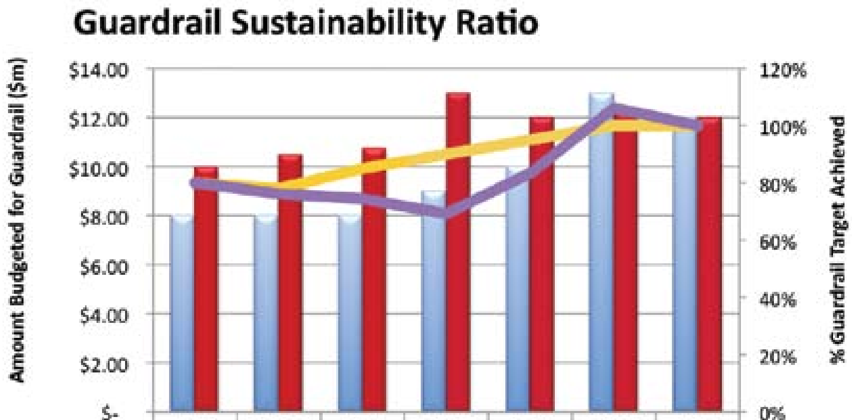


Figure 6. *Pavement deterioration curves.*



	2000	2001	2002	2003	2004	2005	2006
Guardrail Expenditure ($m)	$8.00	$8.00	$8.00	$9.00	$10.00	$13.00	$12.00
Estimated Annualized Amout to Reach Guardrail Target ($m)	$10.00	$10.50	$10.75	$13.00	$12.00	$12.25	$12.00
Guardrail Condition (% of guardrail at target)	80%	78%	85%	90%	95%	100%	100%
Guardrail ASI	0.80	0.76	0.74	0.69	0.83	1.1	1

Figure 7. *Guardrail sustainability ratio calculation.*

budgeted. The yellow trend line and table illustrate that the expenditures from 2001–2004 were below the needed amount to achieve the guardrail target. As a result, only 80 percent of the targeted condition level was met in 2000, falling to 78 percent in 2001. The corresponding Guardrail Sustainability Ratio is then .8 in 2000 falling to .76 in 2001.

Expenditures were increased beginning in 2003. As a result, the backlog was reduced and the amount invested in 2005 actually allowed the department to exceed its target. As a result in 2006 the department decreased expenditures to $12 million, matching the amount needed to achieve the goal. As a result, an ASI of 1.0, the desired level, was achieved.

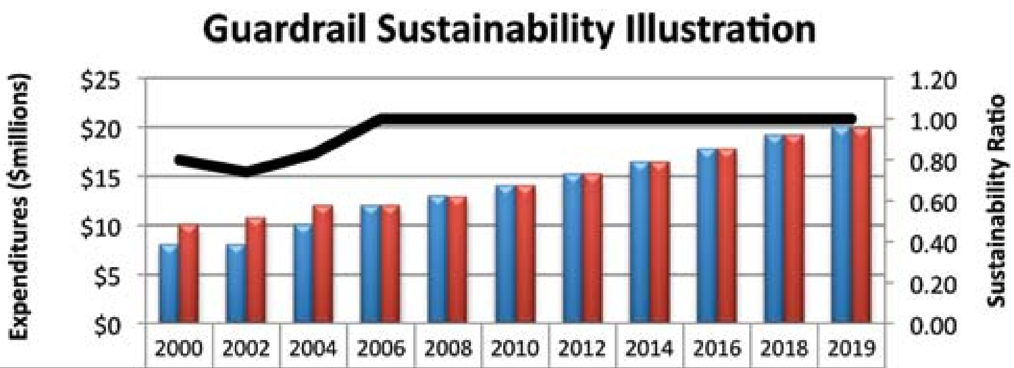
Figure 8 below illustrates that expanding the time series to include more years allows a long-term perspective on the necessary investment. Figure 8 illustrates that if budget year 2011 (highlighted in green and yellow) serve as the current year in which a guardrail budget is to be evaluated that the past expenditure and condition data illustrate the consequences of past investment decisions. Between 2000 and 2005, guardrail investment was inadequate, conditions declined and investment had to substantially increase to correct the backlog.

Budgeting forward, the agency assumes a 4 percent annual increase in guardrail costs and commensurately increases the forecast of guardrail expenditures from $14.60 million in 2011 growing to $19.98 million in 2019. This 20-year perspective provides insight for long-range plans, Statewide Transportation Improvement Programs and other longer-term budgeting and programming exercises. To achieve a 1.0 or optimum Guardrail Sustainability Ratio, the past history of under-investment is numerically and graphically illustrated. Commensurately, the investment needed to sustain conditions at the targeted condition level to the planning horizon year can be demonstrated.

Creating an Index from the Ratios

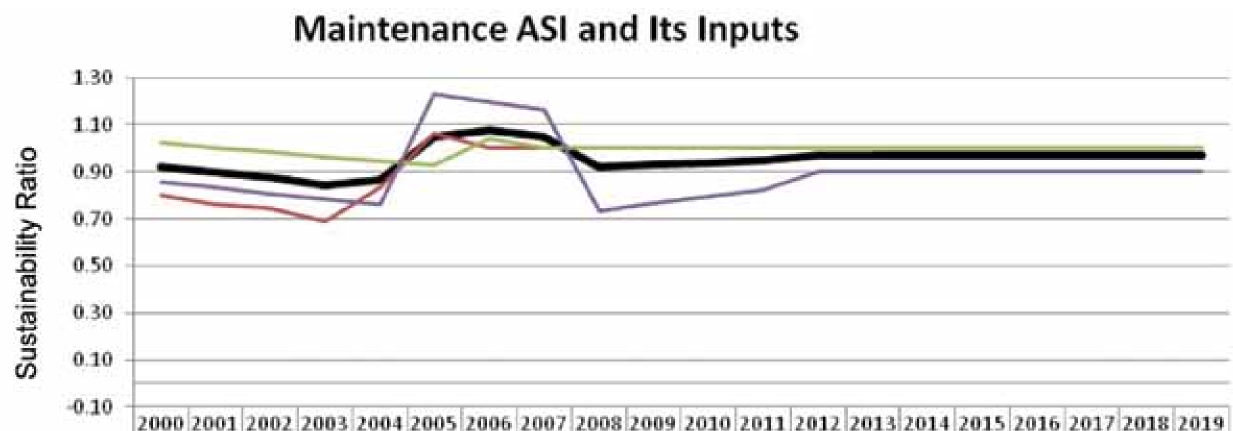
Creating a weighted index from various ratios becomes a simple arithmetic exercise. For the sake of this simple illustration, the Maintenance Sustainability Ratio is derived from the needs and budgets of guardrail, signage and pavement markings. As seen in Figure 9 the three areas of expenditure are summed, both for their need and for their budgets. Total budgets are divided by total need to illustrate how the Guardrail, Pavement Marking and Signage components comprise a Maintenance Sustainability Ratio.

Similarly, the budget and needs of all pavement systems and bridge systems can be illustrated. With this type of reporting, not only can the sustainability



	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2019
Guardrail Expenditure ($m)	$8.0	$8.0	$10.0	$12.0	$13.0	$14.0	$15.2	$16.4	$17.8	$19.2	$20.0
Need	$10.0	$10.8	$12.0	$12.0	$12.9	$14.0	$15.2	$16.4	$17.8	$19.2	$19.9
Guardrail Ratio	0.80	0.74	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 8. *Long-term investment perspective.*



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Combined Maintenance ASI	0.92	0.90	0.88	0.84	0.87	1.05	1.08	1.05	0.92	0.93	0.94	0.95	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Guardrail ASR	0.80	0.76	0.74	0.69	0.83	1.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pavement Markings ASR	1.02	1.00	0.98	0.97	0.95	0.93	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Signage ASR	0.86	0.83	0.81	0.78	0.76	1.23	1.20	1.16	0.73	0.77	0.80	0.83	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

Figure 9. *Combining ratios into an index.*

of overall investment levels be evaluated but the granularity of reporting by infrastructure category allows the reporting to clearly indicate which infrastructure types are not meeting targets. As will be seen in the later case studies, in the current environment of greatly constrained budgets, States are making difficult tradeoffs. In at least two cases that will be illustrated, rural pavement conditions are deteriorating because limited highway agency funds are being invested to sustain conditions on more the heavily travelled major routes such as the National Highway System. In another State, bridge investment was substantially increased while pavement conditions declined.

The granularity of the ASI and ASRs as presented here allow for the reporting of the consequences by asset class of investment decisions. This granularity also is discussed in Chapter 8. There, the GASB 34 reports are discussed and how their lack of granularity by asset class can mask significant declines in important asset classes, such as pavements.

Addressing Need

As noted, the sustainability ratio and indices are based on dividing the amount budgeted for infrastructure preservation by the amount needed. A strong emphasis is placed upon "preservation" as opposed to capacity. The intent of the ASI is to address condition, not performance.

A common process for determining the amount needed for infrastructure preservation does not exist in the United States. There is no standard template an agency can follow, as there is for determining the amount of needed highway capacity at a given location. The Highway Capacity Manual establishes protocols for how to determine the current level of service for the performance of intersections, interchanges, and roadway segments. The standardized HCM process has been further simplified into "plug and chug" software whereby technicians can input given variables and the software will output levels of service that can indicate how many lanes or other capacity enhancements are needed to achieve a given level of service. The level of service analysis is inherently forward-looking in that its standards require development of adequate capacity for a facility to meet traffic demands for a horizon of 20 years.

In the Australian examples cited later in this report, Australian officials note that they need to improve upon the standard reporting formats to determine needed infrastructure investment. As advanced as their asset management practices are, they still have not developed a standardized reporting process used uniformly by local transportation agencies. One of the shortcomings the Australian officials note with their asset sustainability reporting is the lack of common denominators when computing need.

The Supplement to the AASHTO Asset Management Guide Volume II: A Focus on Implementation discusses Transportation Asset Management Plans in a generalized fashion. It describes the inputs and steps but does not elaborate in detail as to how to calculate the needed level of investment to sustain conditions for a given class of assets, or for the highway network overall.

Although no standardized format or process exists for reporting the needed amount of investment for a total inventory or network, the basic components of such a report are apparent from a number of sources. These sources are the Asset Management Guide, volumes 1 and I, the International Infrastructure Management Manual and from the various reports produced by advanced asset management transportation agencies, such as those referenced in this report. The determination of need would be based upon a series of steps including at least the following:

- The agency would rely on explicit policies that call for an asset management approach that emphasizes systematic life-cycle analysis for individual assets and for entire asset inventories
- Asset inventories would be comprehensive, current and accurately reflect asset conditions to a level of detail which enables appropriate treatments to be identified
- The agency would have clearly articulated treatment strategies and protocols so that the appropriate preventive, reactive, rehabilitative and replacement treatments are applied at the appropriate point in the asset's lifecycle
- Deterioration curves are established and applied to assets, and key asset components
- Unit costs to estimate treatment costs would be sound
- The agency would possess scenario-forecasting ability to identify at network levels the conditions of assets and the levels of preventive, reactive, rehabilitative and replacement treatments needed
- Desired and acceptable levels of service targets are established.

As will be seen later in the case study examples, the degree of detail and granularity that the individual States use to develop their "need" estimates varies. For bridges, Ohio uses four generalized components, while North Carolina uses several dozen. Some States use standardized deterioration curves from spreadsheets applied to inventories while others use commercial pavement and bridge management systems with sophisticated optimization routines. The strategies for determining need vary but all are based on defensible, replicable and transparent analyses that are rooted in sound policy and are tempered by good engineering and economics.

The "needed" investments assumed for this report also are tempered by judgment particularly when applied to some very expensive items such as pavement rehabilitation. Much of the U.S. Interstate Highway System was built in the 1960s. A good deal of the original pavement bases remain, and thousands of lane miles of those routes technically warrant pavement rehabilitation or replacement. The collective cost of the total lane miles that warrant rehabilitation or replacement in the next 10 years would be in the tens of billions of dollars nationally and could consume a majority of the entire Federal-aid highway program. Although from a pavement-management perspective those lane miles warrant replacement, including all of them unquestioningly as "need" can erode the credibility of the need estimate for two reasons. First, from a maintenance of traffic standpoint, most urban areas could not tolerate a majority of urban pavements being replaced within a ten-year window. Second, in congested urban areas there is unlikely to be consensus to make 40-year pavement investments that replace pavements inkind without also addressing needed geometric and capacity improvements. Those improvements further drive up the project costs and blur the lines between preservation and capacity. In including costs of major items such as pavement rehabilitation, the "need" forecast is expected to be tempered with sound judgment that rationally identifies a realistic amount of rehabilitation that can be accommodated in the horizon period. As with many other elements of transportation planning, a balance of technical analysis and executive judgment are evident in the "need" estimates reviewed for this report.

Addressing Outliers

As has been mentioned, the Sustainability Index and Ratios are proposed to be planning, programming, communication and long-term budgeting tools. As such, they represent generalized models. They are not intended to possess the detail needed to satisfy short-term accounting reports or engineering estimates.

Also, the ratios and index are intended to address the typical types of infrastructure assets that transportation departments manage and not to address all assets. Outliers exist that need to be addressed separately. These outliers could include the maintenance, preservation and repair/replacement costs of items such as aged, high-cost unique bridges, or the repair of pavements in very high-volume highways, or the replacement of structures under very-high traffic volumes. These types of assets can have much higher-than-average costs that skew the basic unit costs used in these calculations. For instance, historically significant major bridges have unique costs that do not lend

Figure 10. *Kentucky's Charles Roebling suspension bridge is an example of a unique asset.*

themselves to be generalized in the standardized unit costs used in the calculations of this report.

One typical way to address this issue is to separately categorize and plan for these high cost facilities as a separate class of assets. States have grouped their unique and high-cost bridges and planned for them separately. Each such unique structure generally requires a more detailed engineering analysis to determine its preservation needs and costs for a long horizon, such as 10 years. By categorizing these structures and assessing them individually a more accurate planning estimate for their investment can be developed. Generally, they represent a small percentage of a highway agency's overall bridge inventory so that analyzing them separately does not represent additional effort beyond what is normally conducted to monitor such prominent assets.

CHAPTER 2

Private Sector Precedents

State Departments of Transportation face increasing demands from the public, the media and from legislators to document their performance. Major calls for a performance-based Federal-aid highway program have come from the Government Accountability Office, the National Surface Transportation Policy and Revenue Study Commission, the American Association of State Highway and Transportation Officials (AASHTO) and from the Federal Highway Administration (FHWA.)

State and Federal transportation agencies generally embrace these calls for greater accountability and a significant number of State transportation agencies produce extensive performance metrics. Collectively, however, it has been a complex undertaking to find measures that all the State agencies agree upon, and which are uniformly available across all 50 States, the District of Columbia and Puerto Rico.

Although performance measurement is becoming common among State transportation departments, it has been a long-standing practice in the private sector. The lessons of the private sector indicate that measures such as the Asset Sustainability Index play an important performance-measurement role, particularly for capital-intensive organizations.
A basic business-finance textbook would include numerous capital-investment metrics that are commonly used to evaluate the health, or sustainability, of a publicly traded company.

These would include metrics such as the Repair and Maintenance Ratio. This metric is directly analogous to the ASI in that it is derived by calculating:

$$\frac{\text{Repairs and Maintenance}}{\text{Fixed Assets}} = \text{Repair and Maintenance Ratio}$$

In this calculation the expenditures for repairs and maintenance are tracked over time and compared to the value of the company's fixed assets, such as buildings, assembly lines or key assets such as railways for a railroad. Failure to invest adequately in this type of critical equipment will lead to future financial liability as unaddressed repairs accumulate creating higher future costs. In addition, the "book value" of the company declines because its assets are degraded and financially less valuable. Third, the reliability of the company decreases with aging infrastructure. In short, the Repair and Maintenance Ratio would be a common metric for a private-sector business.

Similarly, a Maintenance and Repair Index would roll up or combine several categories of asset types. A Repair and Maintenance Ratio could be calculated for various categories such as buildings, rolling stock, manufacturing equipment, foundries or other asset types. This index could include calculations such as:

$$\frac{\text{Labor, Equipment to Maintain Assets}}{\text{Total Labor and Equipment Costs}} = \text{Maintanence and Repair index}$$

Tracked over time the Maintenance and Repair Index could provide insight in at least three areas. First, if maintenance costs continue to rise, it can indicate that aging equipment is consuming disproportionate resources. A lack of adequate investment could indicate future performance problems. Third, the index could indicate that certain assets within the company are not receiving adequate maintenance.

Several types of Fixed Asset Ratios are commonly used in private sector finance with each ratio providing different types of insight. When the value of fixed assets is divided by debt, the ratio provides insight into whether the company has incurred excessive debt to sustain its fixed assets.

$$\frac{\text{Fixed Assets}}{\text{Short or Long-term Debt}} = \text{Fixed Assets to Debt Ratio}$$

Another calculation indicates whether the company's fixed assets are increasing or decreasing compared to the company's net equity.

$$\frac{\text{Fixed Assets}}{\text{Net Equity}} = \text{Fixed Asset Ratio}$$

A change over time in this ratio could indicate whether the important physical assets of a company are increasing or decreasing. By itself, this change may not be of concern unless it indicates that the company has too much capital tied up in illiquid physical assets.

Analogous Railroad Capital Performance Measures

The Class I railroads provide an analogous reporting example to transportation departments. Like transportation departments, railroads are capital intensive and their primary product is to provide mobility. While transportation departments are under scrutiny from the public and legislators, the railroads are under intense public scrutiny from investors, who are provided significant disclosure by reporting requirements of the Securities and Exchange Commission. (SEC) Railroads and other publicly traded companies must provide annual reports and other disclosures that allow investors to understand the performance of the company, and how it invests the company's resources, which are actually owned by the millions of shareholders.

For railroads, performance data necessary to calculate asset investment measures are reported. For instance in the 2010 annual report of the Norfolk Southern Railroad, the degree and adequacy of its capital investment are among the key metrics presented.

The capital expenditures on track, railcars, locomotives and other long-term assets grew 25 percent over the preceding five years. They are predicted to rise to $2.2 billion for 2011, which would be an 87 percent increase compared to 2006. The amount spent on capital ranges between 80 percent and 120 percent of the company's net income or profit. The insight such metrics provide to investors is to inform them whether the company is sustaining its critical assets for long-term viability. On paper, the company could nearly double its net income or profits in the short-term by cutting its capital investments. However, such a short-term move would not translate into higher stock prices because investors could see that the long-term viability of the company was sacrificed. The condition of track, locomotives, switches, dispatching computers and radios are key components of rail's reliability. Without high reliability ratios, the railroad would lose market share to trucking or other competitors. In short, the adequacy of capital investment to ensure their long-term viability is a key railroad performance metric valued by investors.

Norfolk Southern breaks down its capital investments to provide important granularity for stock analysts and investors. These expenditures include both capital investments and maintenance activities such as maintaining the rail surfaces, replacing ties and investing in rolling stock. For instance, the railroad has the following miles of track: (See Table 4).

Table 3. *Norfolk Southern RR assets and capital expenditures.*

	2011	2010	2009	2008	2007	2006
Total Assets		$28,199	$27,369	$26,297	$26,144	$26,028
Operating Revenues		$9,516	$7,969	$10,661	$9,432	$9,407
Net Income		$1,496	$1,034	$1,716	$1,464	$1,481
Capital Expenditures	$2,200*	$1,470	$1,299	$1,558	$1,341	$1,178
*estimated	*Source: 2010 NSF RR annual report (all figures are in millions)*					

It reports its maintenance and investments on these railways to be: (see Table 5).

As can be seen, an average of 5,000 miles of track are resurfaced annually. Resurfacing consists of maintaining and adjusting rails and ties to be level and parallel which prevents derailments and other problems. A steady and predictable amount of preservation and maintenance of track surface and ties is regularly set aside from the company's finances. With 36,349 miles of track, 9,121 are for very low-speed switching yards, while another 27,220 are for mainline and sidings. Of those, the more than 5,000 miles of resurfacing annually means that every mainline mile would be resurfaced approximately every 5.1 years.

These indicate that while its rolling stock is aging from the 2006 averages, it is retiring old locomotives sooner and getting them out of service. With the railroad consuming 440 million gallons of diesel fuel, the efficiency of locomotives is a significant expense.

In 2009, famous investor Warren Buffet of the Berkshire Hathaway, Inc. holding company made the largest single investment ever for the company when he purchased the outstanding shares of BNSF Railway for $34 billion. In his annual letter to shareholders in 2010, Buffet said he was attracted to BNSF as a long-term investment because of likely long-term economic growth that will increase freight volume, of which BNSF moves approximately 11 percent of all intercity ton miles. He also noted that the BNSF will remain profitable and attractive if Berkshire Hathaway continues the substantial infrastructure investment in BNSF that has made the company successful in recent decades. He referred to the "social compact" Berkshire Hathaway has with society to continue sustaining the infrastructure of this important railroad, and other holdings such as its utility companies.

"All of this adds up to a huge responsibility," he wrote in his shareholders letter. "We are a major and essential part of the American economy's circulatory system, obliged to constantly maintain and improve our 23,000 miles of track along with its ancillary bridges, tunnels, engines and cars. In carrying out this job, we must anticipate society's needs, not merely react to them. Fulfilling our societal obligation, we will regularly spend far more than our depreciation, with this excess amounting to $2 billion in 2011. I'm confident we will earn appropriate returns on our huge incremental investments. Wise regulation and wise investment are two sides of the same coin."

In its final company annual report before being bought by Berkshire Hathaway, BNSF reported that its total capital expenditures had risen significantly over the past five years, resulting in unprecedented system efficiencies (see Table 7 on next page).

Like Norfolk Southern, it reported consistently growing investments in basic capital repair and maintenance including: (see Table 8 on next page).

The degree of investment over time by railroads is reported as one of the major metrics by stock analysts, including the Morningstar service. As seen in Figure 11 (see page 19), the overall capital spending on track and equipment for Norfolk Southern, CSX railroad and Canadian National has steadily increased.

Table 4. *NSC track mileage.*

Miles of Road	Second Tracks	Passing, Crossover	Yards and Switching	Total
20,183	4,663	2,382	9,121	36,349

Table 5. *NSC maintenance targets.*

	2010	2009	2008	2007	2006
Track miles installed	422	434	459	401	327
Track miles resurfaced	5,326	5,568	5,209	5,014	4,871
New crossties installed	2,600,000	2,700,000	2,700,000	2,700,000	2,700,000

Table 6. *NSC rolling stock metrics.*

	2010	2009	2008	2007	2006
Freight Cars	31.0	30.3	29.9	30.1	30.0
Locomotives	20.5	19.9	18.9	18.1	17.7
Retired Locomotives	28.4	31.2	34.4	30.0	35.0

Table 7. *BNSF financial metrics.*

	2009	2008	2007	2006	2005	2004
Revenues		$18,018	$15,802	$14,985	$12,987	$10,946
Net Income		$2,115	$1,829	$1,889	$1,534	$805
Total Assets		$36,403	$33,583	$31,797	$30,436	$29,023
Capital Expenditures	$2,800*	$2,175	$2.248	$2.014	$1,750	$1,527
*estimated	*Source: BNSF 2008 annual report*					

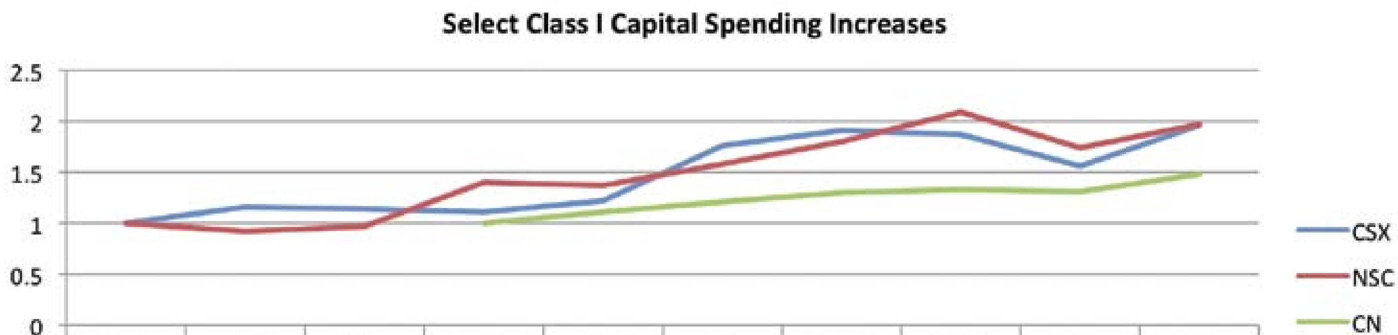
Table 8. *BNSF capital investments.*

	2008	2007	2006
Rail	$429	$376	$304
Ties	$358	$316	$311
Surfacing	$230	$235	$214
Signals, bridges, right of way improvements	$544	$432	$397
Total Engineering	$1,561	$1,359	$1,226
Mechanical	$168	$141	$152
Other	$133	$105	$121
Total Replacement Capital	$1,882	$1,605	$1,499
Information Services	$83	$75	$65
New locomotive, freight cars*	$8	-	-
Terminal and line expansion	$222	$568	$450
Total	$2,175	$2,248	$2,014
(all figures in thousands)			
** (leasing and other acquisition strategies reduce this capital item)*			

Balanced Score Card Analogies and Triple Bottom Line

The private sector's use of performance metrics significantly predates their use in the public sector and generations of private-sector authors have critiqued the value of various performance metrics. In 1991, the Balanced Scorecard was proposed by two authors (Norton and Kaplan) as a way to improve managers' decision making. The Balanced Scorecard addresses the need to balance competing objectives whenever decisions are made, or when performance metrics are reviewed. For instance, a company wants to be profitable but not to the point that it overcharges customers and cuts quality, which long-term would endanger the firm's success. The Balanced Scorecard provides managers with sets of performance metrics that allow them to balance competing interests and to "chose a happy medium" between competing objectives.

Measures such as the ASI and its related ratios would have private sector analogies within a Balanced Scorecard approach. Four major areas of performance are reviewed and considered within a Balance Scorecard including financial performance, internal process performance, learning and growth and customer satisfaction. An organization would need to balance performance within all four areas, and not just one or two of them, to be successful for the long term. For instance in an infrastructure analogy, a performance measure from the International Roughness Index would be very important from the customer perspective because the performance measure directly relates to ride quality. However, from a long-term Transportation Asset



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CSX	1	1.16	1.14	1.11	1.22	1.76	1.91	1.87	1.56	1.96
NSC	1	0.92	0.97	1.4	1.37	1.58	1.8	2.09	1.74	1.97
CN				1	1.11	1.21	1.3	1.33	1.31	1.48

Figure 11. *Class I capital investment growth.*

Management approach focusing maintenance strategies only on IRI can lead to lack of focus on strategies such as preventive maintenance, rehabilitation or reconstruction. Over time, a focus only on IRI does not necessarily lead to the lowest-lifecycle-cost approach which is a critical financial performance metric.

The financial metrics often used in a Balanced Scorecard relate to short-term issues such as company profitability but also to long-term issues such as financial sustainability. An Asset Sustainability Index directly relates to such long-term financial health metrics. Metrics that only evaluate current and past pavement or bridge conditions are inherently lagging metrics. An Asset Sustainability Index is a leading index and provides insight into likely future outcomes of current decisions.

The Balanced Scorecard has some similarities to the Triple Bottom Line approach. It originated in the 1990s and addressed measuring organizational performance based on "profits, people and planet." For a private sector organization, it would mean measuring the company's profitability but also its impact on its community and employees, as well as its impact environmentally. Some public-sector organizations have adopted the triple bottom line by measuring their impact environmentally, upon communities and by measuring their long-term fiscal sustainability. An organization that is not financially sustainable creates future liability for its stakeholders. Measures such as the ASI and ASR lend insight into the long-term sustainability of asset investment.

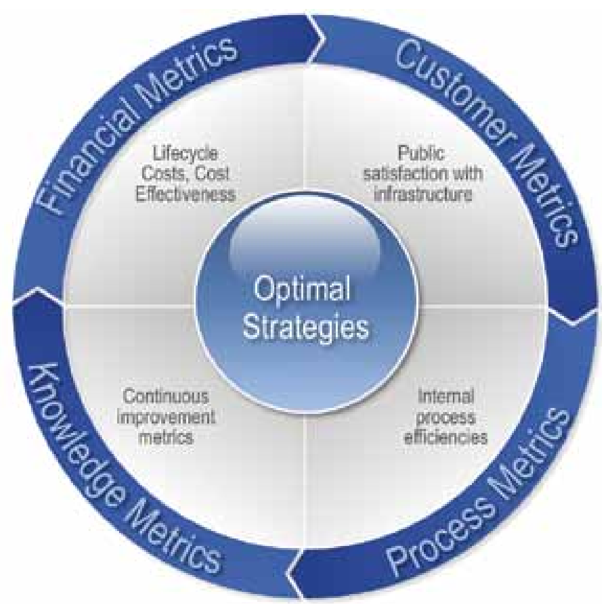


Figure 12. *The Balanced Scorecard.*

Summary

Mature performance management systems such as those used by railroads include asset-investment metrics analogous to the Asset Sustainability Index. Also, advancements in performance measurement systems such as the Balanced Scorecard and Triple Bottom line focus upon fiscal sustainability as a key consideration. As U.S. highway agency performance measurement matures, measures such as the ASI can help them evaluate not only short-term, lagging performance, but can also provide them a leading indicator of likely future performance.

CHAPTER 3

International Precedents

The preceding sections describe the Asset Sustainability Index and illustrate its precedents in the private sector. The following section describes several international examples of precedents for an ASI. It examines in particular how in Australia a very similar Asset Sustainability Ratio was implemented in 2010.

Australian Practices

The three Australian States of Queensland, Victoria and New South Wales have been known for more than a decade for their TAM practices. Those practices gradually expanded to include elements of long-term financial sustainability. While the concept of long-term financial sustainability is not widely discussed in the United States, it is in Australian government circles. Former Australian Prime Minister Kevin Rudd in a 2008 address to the newly formed Australian Council of Local Governments (ACLG) urged a discussion about infrastructure needs that was based upon long-term asset management plans developed in concert with long-term financial sustainability plans.[1] The Prime Minister indicated that such a discussion was not possible at that time because of inconsistent financial reporting processes among the local governments. National guidelines for such reporting would enhance national understanding of infrastructure needs by:

- Ensuring a consistent approach to asset management and financial reporting is implemented for all governments
- Enable a consistent picture of the financial position of local and State governments—including their asset management responsibilities
- Provide the basis for a discussion about best practice in State and local government financial and asset management planning.

Several of the typical statutes, accounting standards and reports that illustrate the evolving concepts of asset sustainability reporting in Australia are summarized below. These references are not exhaustive, but rather illustrative, of the evolving Australian practices.

Queensland Infrastructure Sustainability Reporting Requirements

The Queensland (Australia) Local Government Act of 2009 advances earlier State-required infrastructure reporting statutes to include reports of whether local governments are investing sufficient amounts in infrastructure to ensure their financial sustainability for future generations. As the Act says in Part 3 Section 101:

> "(1) To ensure that local governments are financially sustainable, each local government must implement systems to meet the following financial sustainability criteria—
> (a) financial risks are to be managed prudently;
> (b) financial policies are to be formulated—
> (i) to ensure a reasonable degree of equity, stability and predictability; and
> (ii) so that current services, facilities and activities are financed by the current users of the services, facilities and activities; and
> (iii) having regard to the effect of the policies on the future users of services, facilities and activities;
> (c) full, accurate and timely information about the local government's finances and infrastructure … is to be made available to the public on the local government's website.
> (2) A local government is ***financially sustainable*** if the local government is able to maintain its financial capital and infrastructure capital over the long term."

The State statute requires that the local governments develop a 10-year financial forecast that complements a 10-year asset management plan. The agencies' budgets and financial plans must include reports of capital expenditures and whether they balance with asset depreciation charges. The decline or change in asset conditions is to be reported on balance sheets and compared against the levels of infrastructure investment. Such reporting provides transparency as to the long-term sustainability of each government's assets, including highway assets. Also, an annual report as to the implementation of the plans is required.

The Queensland Department of Local Government and Planning's implementation guidelines stress that the State now considers long-term sustainability of assets to be an important component of determining the health of governments.[2]

"The existence of asset management plans for key infrastructure assets is a necessary predecessor to local governments having a comprehensive long-term financial plan that supports planning and decision-making processes," it states. "This long-term planning for the infrastructure assets allows councils to understand the future financial commitments, and to develop strategies that address key strategic issues such as the local government's approach to service provision and service levels, its debt borrowing policy and revenue policy—including its rating methodology. A local government needs to clearly understand what its future commitments are in order to prepare budgets properly."

It notes that the emphasis of the Local Government Act is to shift financial planning and discussion from the short term to the long term. "The long-term financial forecasts rely on a clear perspective of the long-term infrastructure funding needs of the local government, including maintenance, operations and infrastructure renewals. Without this, a long-term financial forecast for a local government is indicative at best."

The guidelines go on to say that the concept of asset sustainability is still emerging but that the 2009 statutes puts in place processes to make it a standard part of the State's governance of infrastructure planning. Inherent in the process of sustainability is the need to develop meaningful, goal-driven asset management plans. The guidelines go on to say:

"Local governments should look to ensure that:

- Asset management plans are in place, and that the councilors have considered the services, service levels, costs and risks associated with the services offered
- The financial forecasts associated with the assets have been linked to a long-term financial forecast (very few local governments in Queensland have done this to date)
- The local government consistently reviews its operations, looking for more efficient ways of delivering the service.

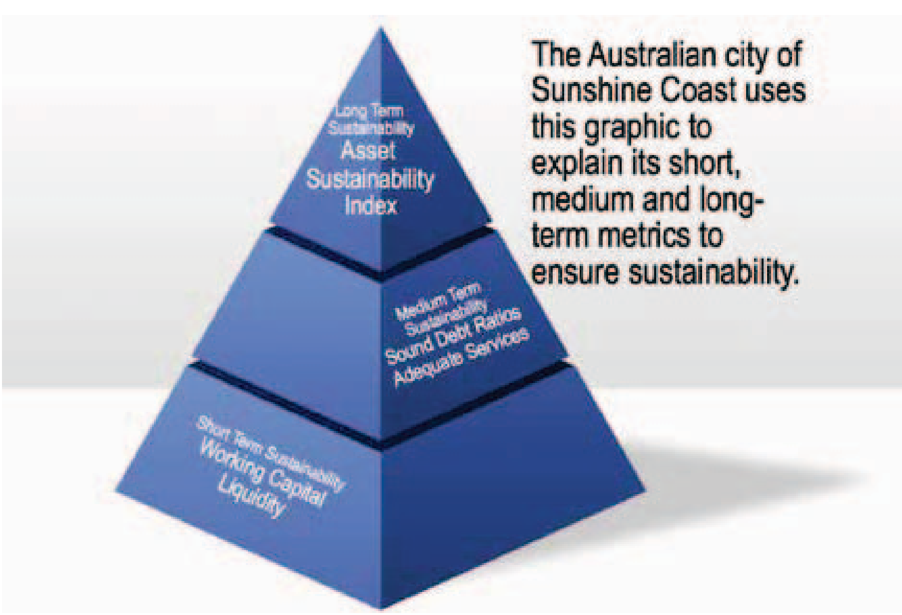


Figure 13. *Sunshine Coast short-term, medium-term and long-term metrics.*

Financial sustainability is about local governments being able to maintain their infrastructure capital and financial capital over the long-term. … The essence of the new *Local Government Act 2009* is achieving financial sustainability and improving planning in the long-term."

As noted in the second bullet above, the development of long-term financial infrastructure indicators is a work in progress. As the act was only implemented in 2009, not all governments have refined the required reports. Of those that did, not all were completed in comparable ways that allow cross-jurisdiction comparisons.[3] However, the implementation of the 2009 act has begun the process of measuring the long-term fiscal sustainability of infrastructure assets in Queensland and some early examples of these reports are listed below.

In its first annual report after enactment of the 2009 Act, the Queensland Department of Infrastructure and Planning published an analysis of the local governments' assessment of their overall sustainability, including for highway infrastructure. As a work in progress, the department noted that long-term highway and other forecasts were largely "indicative" and not definitive because of a lack of consistency and completeness in the asset management plans of agencies, particularly smaller ones. The first year assessment indicated that most local governments were able to prepare long-term financial forecasts and develop financial strategies. However, the asset management plans were not fully sufficient to link them to the financial strategies.

The local governments were investing significant sums into infrastructure renewal and preservation but most were predicting a decline in such investments in the later years of the 2009–2019 period. The Department of Infrastructure and Planning said it was not yet possible to determine that all the local governments are sustainable because of the lack of adequate asset management plans. It would consider a local government to be sustainable if it:

- Has long-term asset management plans
- Has linked these plans to its long-term financial forecasts
- Can manage the financial implications in the long-term.

The lack of complete, long-term asset management plans was the most common hurdle yet to be overcome. The Department noted that the emphasis is to be on maintaining service capacity of assets into the long-term and that there is a significant difference between measuring current infrastructure conditions and ensuring their long-term performance. The assessment of current conditions provides a "point in time" indicator but that the future assurance of infrastructure adequacy is dependent upon a sound long-term asset management plan tied credibly to a long-term financial plan. The Queensland framework allows for analysis of a number of indicators of a community's health. The analytics are similar to those that a stock analyst would review for a publicly traded company to assess the company's worthiness as an investment candidate. The Queensland analysis looks at issues such as the community's financial reserves, its working capital and its debt-coverage ratios.

Similar metrics are applied to the infrastructure, among them:

- An Asset Sustainability Ratio
- An Asset Consumption Ratio
- Asset Renewal Funding Ratio

The Asset Sustainability Ratio is defined in Queensland as the capital expenditure on the replacement of assets (renewals) divided by depreciation expense.

$$\frac{\textbf{Capital Expenses on Renewal of Assets}}{\textbf{Depreciation of Assets}}$$

It is expressed as a percentage. It is an approximation of the extent to which the infrastructure assets managed by the local government are being replaced as they reach the end of their useful lives. The depreciation expense represents an estimate of the extent to which the infrastructure assets have been consumed in a period. Capital expenditure on renewals (replacing assets that the government already has) is an indicator of the extent to which the infrastructure assets are being replaced as they reach the end of their useful life.

The Asset Consumption Ratio is the value of infrastructure assets divided by gross current replacement cost of infrastructure assets.

$$\frac{\textbf{Current Value of Assets}}{\textbf{Replacement Cost of Assets}}$$

It is expressed as a percentage. This ratio shows the current value of a government's depreciable assets relative to their "as new value" in current prices. This ratio seeks to highlight the aged condition of the stock of physical assets.

The Asset Renewal Funding Ratio is the net present value of the planned capital expenditures on renewals over 10 years divided by the net present value of the required capital expenditures on renewals over the same period.

$$\frac{\text{NPV of Capital Invested Over 10 Years}}{\text{Needed Investment to Sustain Assets}}$$

It is expressed as a percent and it represents the extent to which the required capital expenditures on renewals per the asset management plans have been incorporated into the 10-year financial model of the local government.

This initial year's analysis indicates that for the 49 local governments reporting that for the early years of the first forecast period they appear to be investing sufficient sums in infrastructure to offset the depreciation, or deterioration, expected. The sums reported below in Table 9 are for all infrastructure including highways, buildings, water supplies, drainage systems and retaining walls. For roads and transport networks the reports indicate the 2009/2010 investment in "renewals" were $908 million ($AUS) compared to depreciation of $621 million ($AUS.) An additional $1 billion was invested in new or upgraded roadways. Superficially, those numbers indicate that sufficient amounts are invested to offset depreciation. Although initially promising, the Department of Infrastructure and Local Government reports several caveats of concern. First, is that the asset management plans were not adequate to determine if the current level of investment will be sufficient to address future deterioration. Second, the amount of new construction appears to be unsustainable and will lead to new roadways that will require higher levels of future maintenance. Third, the future year forecasts indicate declining levels of investment in renewals that could indicate that current levels of renewal investment cannot be sustained. As noted, the Asset Sustainability Ratio falls from a high of 1.66 to .98. That equates to current expenditures being 66 percent higher than necessary to counteract depreciation while future expenditures fall to only .98 percent of necessary amounts in the 2018/19 period. The report stresses that one-year's funding, such as 2018/19, should not be considered indicative of a long-term trend. However, the declining levels of investment, combined with the high level of new construction and the inadequacy of the asset management plans caused the Department to caution that long-term infrastructure sustainability is not assured in Queensland.

Two of the larger cities in Queensland published draft or final community financial plans that include these new asset indicators. The new reports provide long-term insight into the expected infrastructure investment levels and how those levels will contribute to long-term asset conditions. The cities have completed, or are drafting, the long-term fiscal sustainability plans as well as their long-term asset management plans. The updates to city councils and to the public indicate that the exercises require them to focus upon their rates of asset depreciation and deterioration and to consider whether they have the financial capacity to offset the expected deterioration. For instance, the city of Sunshine Coast notes in its draft Financial Sustainability Plan 2010 to 2020 that it is not presently meeting its asset sustainability ratio targets but through long-term budgeting it is planning to achieve them starting in 2015. Table 10 from the Sunshine Coast City Council Draft Financial Sustainability Plan illustrates its use of these new metrics. Its short-term metrics such as Cash Liquidity reflect the city's short-term financial health. While long-term, it is now relying on the asset-investment indicators to improve its long-term perspective.

In Table 10 (see page 26), it reports its first estimation of its long-term asset indicators, as well as other indicators of long-term financial health. As can be seen, its initial forecast for its Asset Sustainability Ratio ranges from 76 percent to 60 percent , while its target is 90 percent . In its narrative, it notes this performance will require attention and that the city hopes in future budgets beginning in 2015 to increase its infrastructure renewal investment to meet the 90 percent target.

Table 9. *Queensland asset investment indicators.*

	2009-10	2018-19	Average (10 yr)	Difference (10-yr)
Asset Sustainability Ratio	166.5%	98.0%	115.3%	-68.5%
Asset Consumption Ratio	74.3%	70.5%	73.1%	-3.9%

The advancement in public reporting represented by these statements are several. First, they are intended to be much clearer to an average person than would be traditional accounting or engineering reports. Although they are expressed in somewhat technical terms, the reports come with glossaries and definitions to explain their meaning to a lay person. For instance, in Table 10, the Operating Surplus Ratio measures the available cash once operating expenses are met. As seen, the city has currently and expects to have in the future little in the way of excess cash beyond what is needed for currently identified costs. However, its debt ratios are reasonable and its net financial liabilities are well below its target. These indicate that it could increase borrowing in the future. The Asset Consumption Ratio indicates that depreciation will be expected to outpace investment. The Asset Sustainability Ratio shows that with current long-term planned expenditures that its investment in asset renewal could fall to as much as 30 percent below target levels. However, the city has a very high target of 90 percent . That target means, in effect, it wants 90 percent of infrastructure to have almost "as new" value. Second, these reports provide a long-term perspective missing from most financial reports. Generally, financial reports cover two budget years and do not provide insight into the adequacy of long-term infrastructure investment. Third, these financial reports illustrate specifically the forecast for long-term infrastructure conditions. Typical financial reports may indicate short-term budgets for infrastructure but do not address whether those budgets were adequate for long-term sustainability of asset conditions.

The Queensland Bundaberg Regional Council reports the following in its fiscal plan as seen in Table 11 (see page 26).

The Asset Consumption Ratio basically indicates the current, depreciated value of the infrastructure compared to its new, as built cost. So in effect, the city is spending enough over time to keep the infrastructure, in effect, at between 79 percent and 73 percent of it's "as new" condition.

In Figure 14, the City of the Gold Coast depicts its Asset Consumption Ratio in a slightly different format. Again, however, the city is indicating that its long-term infrastructure investment levels appear to be adequate although it is expecting a steady decline in its Asset Consumption performance but within targeted levels.

Asset Valuation within Australian Asset Management

The Transportation Asset Management practices in Australia and New Zealand in the past decade also have evolved to embrace what the Australians call "asset valuation." It is the subset of asset management and auditing practices that captures the long-term depreciated value of infrastructure assets, such as highways. Asset valuation has now become a standard part of the Australian and New Zealand State highway TAM processes. Those practices have been in place longer than they have been for the local governments in Queensland but they still continue to be an evolving work in progress for the State highway agencies.

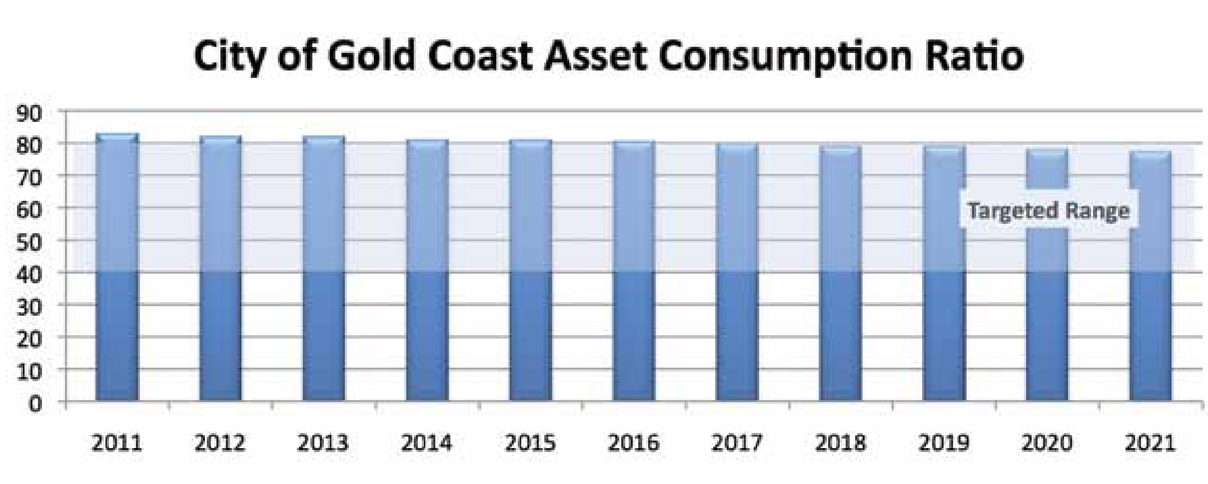


Figure 14. *Gold Coast Asset Consumption forecasts.*

Table 10. *Sunshine Coast asset investment metrics.*

	Target	Actual 2010-11	Estimate 2011-12	Estimate 2012-13	Estimate 2013-14	Estimate 2014-15	Estimate 2015-16	Estimate 2016-17	Estimate 2017-18	Estimate 2018-19	Estimate 2019-20	Estimate 2020-21
Operating Surplus Ratio	0-15%	0.1%	0.1%	0.0%	0.3%	0.9%	0.8%	0.2%	0.1%	0.0%	0.1%	0.3%
Net Financial Liabilities Ratio	<60%	18.2%	21.0%	25.0%	26.0%	23.0%	25.0%	27.0%	27.0%	28.0%	28.0%	31.0%
Interest Coverage Ratio	0-10%	2.9%	(8.7%)	(8.1%)	(7.7%)	(7.5%)	(7.3%)	(7.0%)	(6.7%)	(6.5%)	(6.4%)	(6.2%)
Asset Sustainability Ratio	>90%	76%	77%	66%	69%	61%	61%	61%	60%	60%	60%	60%
Asset Consumption Ratio	40-80%	63%	78%	78%	77%	77%	76%	76%	75%	75%	74%	74%
Debt to Assets Ratio	<10%	5.2%	4.2%	4.1%	4.0%	3.8%	3.9%	4.0%	3.9%	3.8%	3.8%	3.7%
Cash Balance (Months)	6.0	6.0	6.9	5.9	4.9	4.7	4.6	4.3	3.9	3.5	3.1	2.6

Table 11. *Bundaberg metrics.*

	Target	Actual 2009-10	Estimate 2010-11	Estimate 2011-12	Estimate 2012-13	Estimate 2013-14	Estimate 2014-15	Estimate 2015-16	Estimate 2016-17	Estimate 2017-18	Estimate 2018-19	Estimate 2019-20
Asset Consumption Ratio	40-80%	79%	78%	77%	77%	76%	76%	75%	75%	74%	74%	73%
Asset Sustainability Ratio	>90%	130%	163%	163%	145%	164%	128%	117%	117%	117%	113%	136%

The Austroads Guide to Asset Management includes a Chapter 8 on Asset Valuation and Audit. Austroads is the association of State and territorial transportation agencies in Australia and the national transportation agency in New Zealand. It is similar to the American Association of State Highway and Transportation Officials (AASHTO) in the United States. It helps set national standards, facilitates peer interaction and conducts research on emerging issues.

Austroads published the Asset Valuation chapter, which is intended to complement national and State efforts to refine the valuation process among the State and territorial highway agencies. It complements also the Australian Infrastructure Financial Management Guidelines published by the Institute of Public Works Engineering Australia (IPWEA) and the standards of the Australian Accounting Standards Board (AASB.)

In concept and practice, the Chapter 8 Asset Valuation and Audit guidelines are similar to the concepts and practices described in the Queensland Local Government Act. Because of the similarities, the details of the Austroads asset valuation guidelines will not be restated. However, the key additional concepts are added here.

Austroads notes that "sustainability" has evolved a new meaning in recent years to embrace environmental, social and economic prosperity, or a Triple Bottom Line. The 20-year focus of both asset management plans and infrastructure financial plans are intended to ensure that public agencies today do not consume the benefits necessary to sustain future generations. These benefits extend to the economic benefits or economic value of highway infrastructure. Sustainability only is achieved if the infrastructure is managed today to ensure that extraordinary expenditures are not necessary in the future to provide future users the economic benefits of a sound transportation system. In effect, investing adequately today to protect the needs of future users is the essence of infrastructure sustainability.

"If the Agency's long-term finances are sustainable, then disruptive tax increases or spending cuts can be avoided, the taxation burden will be fairly shared between current and future taxpayers and the stability or predictability of government taxes and charges will not be at risk," the guidelines notes.[4]

The guidelines also reflect another evolution, that of transparency to lay readers of financial documents. The guidelines note that agencies should produce financial reports so that they are understandable to readers with only a general understanding of business, economics or accounting. Also, the information should be relevant for decision making. In particular, it should be comparable so that trends over time or trends with other agencies can be compared. In short, the financial documents are intended to evolve and to serve a broad public analysis and budgeting function, rather than a strictly perfunctory administrative requirement.

Two of the essential concepts are the capturing of "useful life" and "economic life" of assets. Presently, data bases such as the U.S. National Bridge Inventory report on the number, size and condition of bridges. From the conditions of the bridge some inference into the "useful life" or the "economic life" of the bridges can be made. Bridges with a structural deficiency rating of a 3 or a 4 clearly would have shorter useful or economic lives than a bridge rated a 9. The Austroads guidelines and other Australian asset valuation efforts seek to quantify and summarize the useful and economic life in a clear fashion. In short, if a new bridge at a given location would be valued at $1 million but the existing bridge at that location is deteriorated and only valued at $100,000, then clearly the existing bridge has less value to the public than a new bridge. If proper repair and maintenance that costs $200,000 can make the bridge function like a newer bridge, then the investment clearly increases the value of the public's assets. Using proper maintenance and repair to leave future generations with a higher-valued set of assets is among the key objectives of the asset valuation process.

The useful life is defined as the period over which the asset is expected to provide services. The economic life is the period until the asset ceases to be the lowest-cost alternative to meet the required level of service. An example would be a pavement that has severely deteriorated so that it no longer provides an acceptable ride. If the pavement is so deteriorated that resurfacings and other less-complex treatments cannot restore its level of service for an acceptable period, it has an economic life of zero. The pavement still exists but its condition is so poor that only an essentially new pavement could provide an adequate level of service for an acceptable cost.

A similar metric that the financial reporting guidelines describe is that of "impairment." An asset is impaired when its reported value is less than the benefits recovered by the use or sale of the asset. Assets become impaired when they are physically damaged or obsolete.

As with the Queensland guidelines, the Austroads guidelines spend considerable effort describing depreciation of assets. Once the full depreciation of an asset is documented, the value of the agency's assets can be compared to its liabilities and the overall financial health of the organization can be determined. A simple test in the private sector of a business's health is to divide its non-current assets by its non-current liabilities, such as dividing the value of its physical plant by its long-term debts such as bonds.

Although couched in financial terms, the guidelines are intended to provide insight into important public policy and public budgeting concerns. These financial ratios are actually performance measures that can be used to judge the health of the infrastructure, the performance of the agency and the performance of the overall government's maintenance of its infrastructure. The "end game" of the Austroads financial guidelines is to allow the measurement of individual assets, the measurement of the agencies that manage the assets and the measurement of the overall government's long-term approach to managing its entire network of assets.

The various financial metrics can be boiled down to several key ones similar to those used in Queensland. These include:

- **Asset Consumption Ratio**—The average proportion of "as new" condition left in the assets. It shows the depreciated replacement costs of an agency's depreciable assets relative to their "as new" replacement value.

- **Future Renewal Funding Ratio**—The ratio of asset replacement funding relative to the capital renewal expenditure identified in the asset management plan. Both the actual replacement funding and the needs identified in the asset management plan are brought back to net present value. (NPV).

- **Asset Sustainability Ratio**—As used in Queensland, it is the current expenditure on asset renewal relative to the depreciation of the assets over that time. (Asset preservation and renewal expenditures divided by the needed level of expenditure.) It measures whether assets are being replaced at the rate at which they are wearing out.

Figure 15 illustrates the actual 2009 and 2010 asset values for Bundaberg, Australia, with forecasts through 2019. This asset valuation analysis is intended to indicate whether the infrastructure investment practices increase or decrease the community's infrastructure "equity."

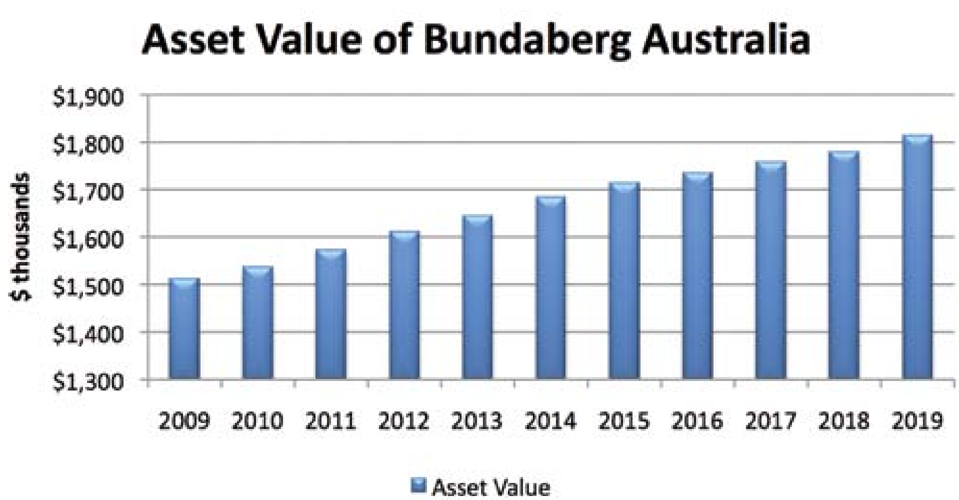


Figure 15. *Asset values in Bundaberg.*

UK Highway Infrastructure Valuation

Since the mid-2000s, the United Kingdom and its local governments have refined their roadway asset valuation processes, with some similarities and differences from the Australian practices. Like with the Queensland example, the UK examples hold relevance for the United States in that the central agencies have developed guidance attempting to standardize asset valuation among many different governments. The intent is to allow benchmarking and comparability, much as is being discussed in the United States. The UK has many similarities to the U.S. governance structure. Obviously, both are industrialized democracies but beyond that the UK has a central government that works as both a "coach" and an "umpire" for many local governments in carrying out central policy. In addition, Scotland, Wales and Northern Ireland have considerable autonomy. Therefore, the English Department for Transport (DfT) sets policy for English highways but not necessarily for Scottish, Welsh or Northern Ireland highways. However, the local governments across Scotland, Wales and England have cooperated on some voluntary asset valuation standards, such as the Guidance Document for Highway Infrastructure Asset Valuation produced by the County Surveyors Society/TAG Asset Management Working Group in 2005. That organization has since changed its name to ADEPT, the Association of Directors of the Environment, Economy, Planning and Transport. The local government benchmarking and cooperation is similar to what occurs between U.S. States through AASHTO.

As in Queensland and as with the U.S. GASB 34 requirements, the British valuation guidance for local governments emphasizes that asset valuation is about accountability and transparency in support of sound infrastructure policy. It says in part:

"A fundamental component of long term planning is to ensure the asset base is preserved and replenished in a sustainable way without imposing an undue financial burden on future generations. The preservation of the asset base can be measured and monitored over time using a robust asset valuation procedure that provides a true and fair value of the assets."[5]

It defines asset valuation as the calculation in terms of monetary value of a government's physical assets. It allows the estimating of the "consumption" of a society's physical assets over time and compares that consumption with the renewal and replacement of assets. It notes that the main drivers for asset valuation are:

1. To emphasize the need to preserve the highway infrastructure by placing a monetary value on highway infrastructure assets.

2. To demonstrate asset stewardship by monitoring the Asset Value over time.

3. To promote greater accountability, transparency and improved stewardship of public finances.

4. To support Highway Asset Management.

The guidance notes that the mere assigning of monetary value to highway assets casts them as an important public asset worthy of preservation. The long-term reporting of the value of the public's assets is an important mechanism for demonstrating stewardship. Monitoring how the value of highway infrastructure is rising or falling indicates if costs are being unduly passed on to future generations. It also provides compelling arguments for sound asset management and sufficient investment. As such, the asset valuation process can produce important metrics that support Performance Management and other forms of public accountability.

By reporting upon changes in asset valuation, overall depreciation and the improvement or impairment of assets over time, the agency can discern if its maintenance practices and investment levels are sufficient to sustain the assets at targeted levels. Analyzing the reasons for assets' decline can lead to improved maintenance practices, improved asset treatments or improved investment levels.

"These programs of work influence the asset value, i.e. the work program may maintain or increase the asset value or, if it is not adequate, then the asset value may decrease. Monitoring asset value over time can therefore be used to demonstrate stewardship of assets. This information provides an important input to a business case for investing in the maintenance and upkeep of public assets."

The British guidance notes that asset valuation does not succeed independently but is part of a suite of sound practices that an agency should incorporate including:

- Treat the assets in the "right way" reflecting that they are part of a highway network and operate together to provide the specified levels of service for the network. This integrated approach to asset management should be reflected, where appropriate, in the procedure used for highway infrastructure asset valuation.

- Reflect good engineering practice and support the right investment choices for maintenance, renewal and improvement works.

- Be sensitive to works that add or protect asset value.

- Be consistent with, and be a component of, the suite of processes used in highway Asset Management such as Performance Measures, prioritization, and whole life costing (lifecycle costing.)

- Support decision making and long-term investment planning by forming an important element of the business case for funding the upkeep of condition and performance of the assets.

- Be relatively straightforward and operate on data that is readily available or can be collected with marginal effort.

In addition, it says tests of the adequacy of the asset valuation process should be that it is reliable, comparable and material. That it is should be free of bias, comparable to analyses of past years or with other agencies and that it focus upon the material issues important to decision makers.

As with the Queensland and GASB processes, key factors in asset valuation include the tracking of depreciation, which is defined as the systematic consumption of economic benefits. The benefits inherent in the asset are consumed through use, age, deterioration or obsolescence. Impairment is the reduction in asset value due to a sudden or expected decrease in condition, such as damage caused by flooding or landslide.

As a method of supporting decision making, ensuring accountability and measuring effectiveness, the guidance recommends three major performance measures. Again, they are similar to the Queensland measures but illustrate different nuances of measurement that provide different insights into performance than those used in Queensland.
The three key measures are:

- **Accumulated Asset Consumption (AAC)—** measures the proportion of the gross asset value that has been consumed to date

- **In-year Asset Consumption (IAC)—**measures the proportion of asset value consumed during the accounting period

- **In-year Asset Renewal (IAR)—**measures the proportion of asset value restored/renewed during the accounting period.

Figure 16 represents an idealized Asset Consumption indicator described in the British guidance.

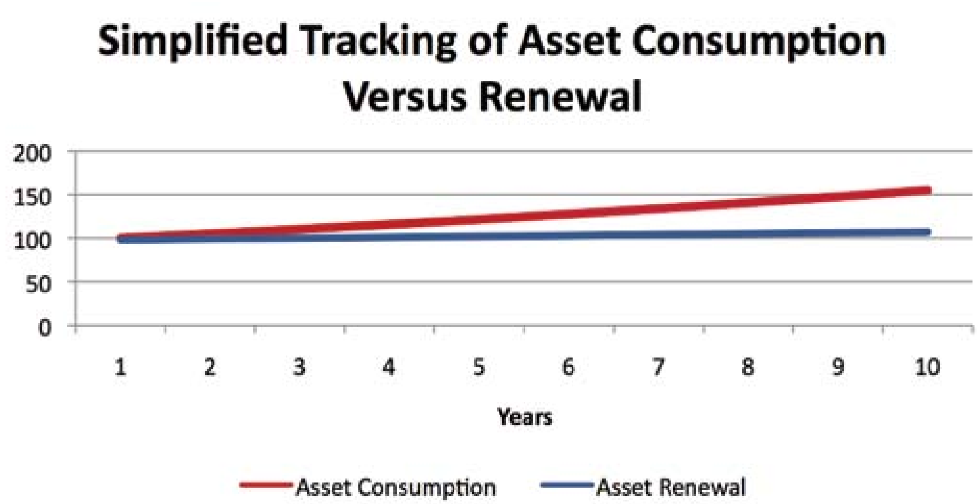


Figure 16. *An idealized example of asset consumption.*

It indicates that over 10 years, the rate of asset consumption or deterioration is outpacing the rate of asset renewal. The overall value of the agency's assets is declining and future users will incur higher costs to restore conditions to the level of year 1. In effect, current users are consuming the assets that future users will need.

CHAPTER 4

Example of a U.S. Pavement Sustainability Ratio

Based on the concepts described in chapters 3, Chapter 4 begins examining how an Asset Sustainability Index could be built using existing U.S. transportation agency data. The index as proposed in this report is a composite of pavement, bridge and maintenance condition data. This chapter begins the analysis by examining the pavement component of the index, which would be a Pavement Sustainability Ratio. When that ratio is combined with the Bridge Sustainability Ratio and the Maintenance Sustainability Ratio, they would form the Asset Sustainability Index as proposed. This example uses pavement condition and expenditure data from the Ohio, Utah and Minnesota Departments of Transportation.

Ohio Pavement Forecasts

The Ohio Department of Transportation (ODOT) produces annual and multi-year reports that illustrate past, current and projected future pavement conditions. The long timeframe of the Ohio DOT reporting is intended to complement its long-standing policy of placing infrastructure preservation as the central focus of its long-term budgeting. Catch phrases for this emphasis have changed over the years with such terms as sustaining a "steady state" of acceptable infrastructure conditions to a "fix it first" approach. The policy approach has been supported by a reporting process that keeps the agency focused on ensuring that its capital budgeting process, its project-selection decisions and its maintenance practices work in concert to achieve stable, long-term infrastructure conditions within the constraints of available revenue.

Inherent in the ODOT infrastructure-management process is a long planning horizon. As seen in Figure 17 above, the agency looks at a nearly 20-year timeframe. The past years provide a trend

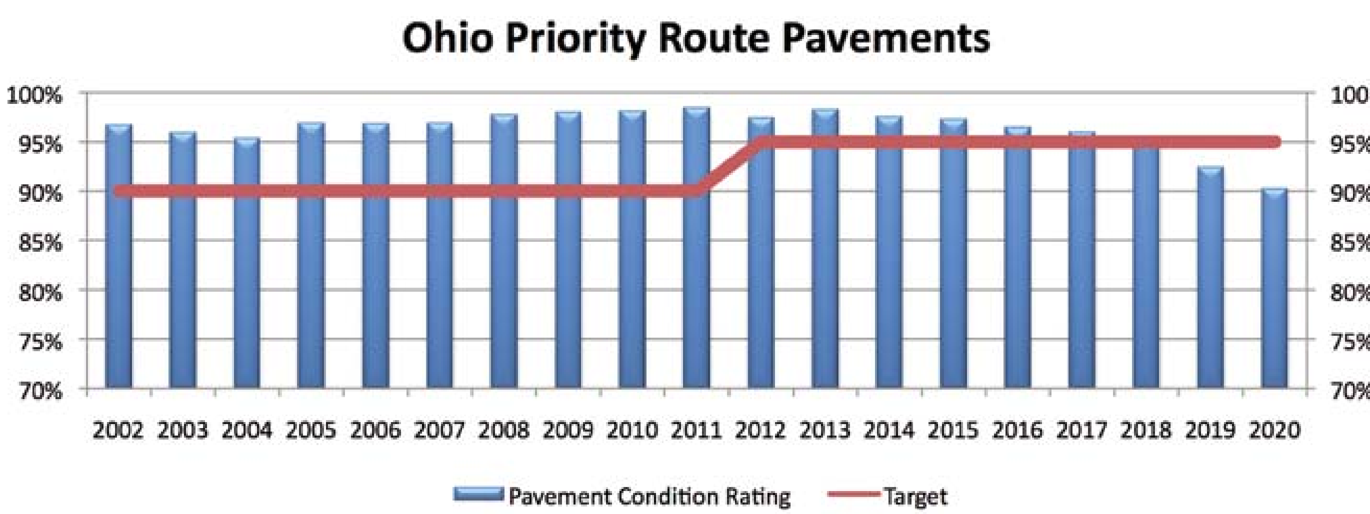


Figure 17. *Conditions on Ohio's 'priority system.'*

line of investment levels and resulting infrastructure conditions that yield a solid analytical baseline for future forecasts. By extrapolating from a long trend line, the agency builds confidence in its pavement deterioration curves and other inputs for its forecasts of future performance. By looking at least a decade into the future for many of its major system elements such as bridges and Priority System pavements, it keeps the agency focused upon substantive planning to ensure steady, long-term conditions. As seen in Figures 17 and 18, the agency has raised the target for Priority System pavement conditions from 90 percent acceptable to 95 percent.

As seen in Figures 17 and 18, the agency has steadily surpassed its system condition goals for its Priority System. The Priority System in Ohio is similar to the National Highway System and it includes the Interstate Highway System and most multi-lane, divided routes. It consists of approximately 26 percent of the State's lane miles but handles 59 percent of the total vehicle miles of travel and 77 percent of the truck travel.[6] The State uses a Pavement Condition Rating (PCR) in addition to the International Roughness Index (IRI.) The PCR is derived from an extensive visual survey of every route annually. The PCR is collected by a central crew of raters to ensure consistency. They measure more than 20 distresses including several that are indicative of structural pavement distresses such as reflective cracking, alligator cracking, pumping on concrete or composite pavements or broken slabs in concrete or composite pavements. The State also has compiled a construction history for every major pavement section, and it has a year-by-year history of past treatments and rates of PCR change by segment. This extensive history allows the department to forecast future conditions based upon scheduled treatments and each pavement's deterioration curve. The department has been stressing Asset Management for the past decade and that has contributed to substantial pavement condition improvements. In the mid-1990s, nearly 20 percent of the Priority System lane miles were below the acceptable PCR threshold of 65 and had substantial rates of annual degradation. As seen in Figure 18 below, the high deficiency volumes of the 1990s were addressed and system conditions have consistently surpassed the State's targets. The forecasted increase in deficiencies in the years after 2018 are largely, but not wholly, attributable to the State's forecasting methods. It forecasts conditions based upon the treatments programmed in the Statewide Transportation Improvement Program (STIP) as reported in the department's project-management system called Ellis. Because projects are not programmed yet for the later years, the Ellis program applies a deterioration curve to each pavement but does not yet capture the expected pavement treatments.

ODOT reports expenditure levels in a fashion similar to that required by GASB, by some of the international financial reporting processes and similar to what is envisioned for the Asset Sustainability Index. Although the details of the financial expenditure processes have changed over the years, the basic concept has been used for more than a decade. As seen below in Table 12 from the Department's amended 2006–2007 Business Plan, pavement expenditures were to rise from $457 million in 2005 to $516 million in 2015. The department manages its pavements in three systems, Priority, General and Urban. The Priority System already has been described, while the General System is basically the two-lane system outside of city limits, which in the "Home Rule" State of Ohio is the DOT's responsibility. The Urban System is basically State and U.S. routes within cities, which in Ohio are a shared responsibility between the State and local governments. As seen in the Table 12, the percentage of acceptable forecasted pavement conditions for the three systems range from a high of 98 percent for the Priority System in 2008 to a low of 90 percent for the Urban System by 2015. The targets for PCR conditions on the General and Urban Systems in 2006 were a PCR of 55.

Table 12 also shows a forecasted financial shortfall in needed pavement investment starting in 2011 and continuing through 2015. In the 2006 scenario, ODOT was forecasting that within five years it would experience a shortfall starting at $139 million annually and rising to $198 million annually by 2015 if the conditions at that time continued. At that time, the major contributory conditions included a substantial increase in material costs which its Business Plan in 2006 indicated had risen at an overall rate of up to 12 percent a year. If those prices continued to escalate, and if the Federal highway apportionments remained virtually unchanged through 2015 as was forecast at that

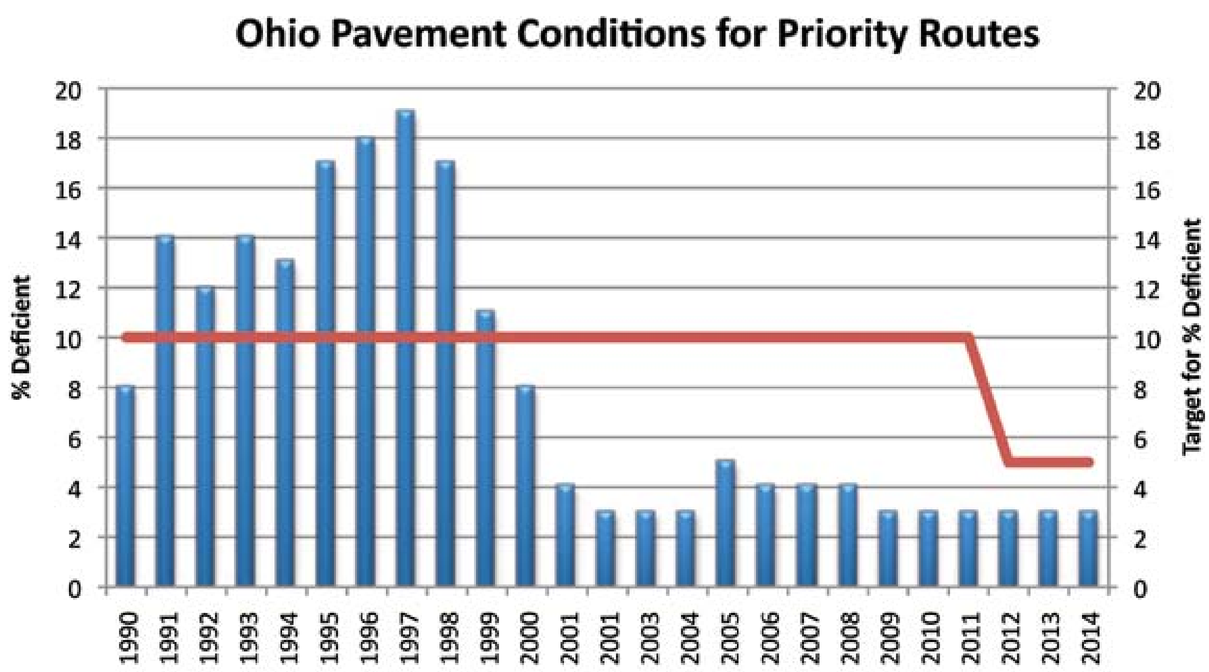


Figure 18. *Ohio pavement conditions over 25 years.*

Table 12. *Ohio pavement expenditures and outcomes.*

Ohio Pavement Expenditures and Condition Results (Actual and Forecast)												
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
General System Two-Lane Pavements	$93	$93	$108	$113	$179	$186	$147	$149	$151	$152	$154	
Percent Acceptable				98%		97%		97%			97%	
Priority System Routine Maintenance	$179	$179	$217	$228	$192	$199	$143	$145	$146	$148	$149	
Percent Acceptable				0.96		0.97		0.97			0.97	
Priority System Rehab and Replacement	$150	$192	$150	$150	$150	$150	$172	$173	$175	$176	$178	
Paving State Routes in Cities	$35	$35	$35	$35	$35	$35	$35	$35	$35	$35	$35	
Percent Acceptable				96%		95%		90%			90%	
Total Pavement Program Budgeted	$457	$499	$510	$526	$556	$570	$497	$502	$507	$511	$516	$4,185
Projected Shortfall for Pavement Program							-$139	-$152	-$166	-$182	-$198	-$837
Source: Amended ODOT 2006-2007 Business Plan												

time, the Department was warning the public and policy makers of an $838 million gap between what was available and what was needed financially to meet its pavement targets.

The financial information and the pavement condition forecasts provided in 2006 allow the illustration of a Pavement Sustainability Ratio for Ohio for this period of 2005–2015 as seen in Figure 19. It is a calculation of the amount budgeted, divided by the amount needed which results in the following as shown in Figure 19. It illustrates that from 2005 to 2010, the level of investment is adequate to sustain pavement conditions at ODOT's targets. With expenditures relatively flat and materials costs forecast to rise, the Pavement Sustainability Index falls from 1.0 - adequate - to .78, or 22 percent below the amount necessary to provide stable, sustainable pavement conditions. Commensurately, a "Sustainability Gap" is illustrated on the secondary vertical axis and represents a cumulative gap of $838 million over the forecast period.

The Ohio DOT produces a long-term pavement condition forecast and that is updated monthly and updated its Business Plan for the 2008–2009 and 2010–2011 biennium to address the earlier forecasts of impending pavement shortfalls. Table 13 depicts the total pavement expenditures for 2010 forecasted through 2017 as updated in the 2010–2011 Business Plan. They illustrate that ODOT increased pavement expenditures substantially, by an average of $109 million annually from 2010–2017, with a commensurate closing of the Sustainability Gap and the achievement of its pavement targets.

Table 14, illustrates the amended spending plan for 2010 through 2017 which was adopted in 2010 to address the under investment in pavements. As seen in Table 14, spending rose by between $139 million in 2011 to as much as $296 million in 2017 to fill the "sustainability gap" and to achieve the target of an Pavement Sustainability Ratio of 1.0. The calculation of the PSR and the computation of the delta to close the gap illustrates clearly the degree of additional investment necessary to sustain the pavement assets at the targeted condition through 2017. In 2006, ODOT forecasted the gap that was likely to occur if inflation continued as predicted. In 2010, when the effects of inflation had not diminished, ODOT increased pavement spending. If ODOT had been unable to redirect the resources into the pavement program, the PSR would have reported to policy makers the future consequences of the underinvestment and the relative size of the underinvestment.

The department balanced several ever-changing variables to develop the updated 2008–2017 budget estimate and pavement forecast. It noted that inflation continued to be a concern but that it had subsided substantially, which reduced the impacts of material costs that were experienced in the earlier Business Plan. However, rising costs on top of the already significant price increases of the past years remains a substantial influence on the pavement program. The Department also further reduced its Major New Construction Program, or the capacity-adding projects, in order to address the pavement gap.

A positive mitigating factor has been the increased service life Ohio has gotten from its pavements. Rates of annual degradation of untreated pavements have improved from a statewide average of 3.3 PCR points annually in the 1990s to as low as 2.5 percent PCR declines in the early 2000s. The difference equates to a 24 percent improvement in the longevity of the average pavement. In an annual pavement report, ODOT attributes improved pavement performance to a number of strategies, including tightened specifications, expanded preventive maintenance and enhanced decision making on treatment selection.

The granularity of the Ohio analysis allows for drilling into the underlying conditions that influence overall statewide pavement performance. This ability to "drill down" would allow the creation of a Pavement Sustainability Ratio for each district, each county or for any other subdivision, such as the highways within a Metropolitan Planning Organization boundary. This granularity would allow an ODOT District or the neighboring MPOs to report on the PSR and total Asset Sustainability Index of its region. With the magnitude of a PSR known, the State, district or MPO could adopt long-range programming and pavement preservation strategies to sustain the pavement inventory.

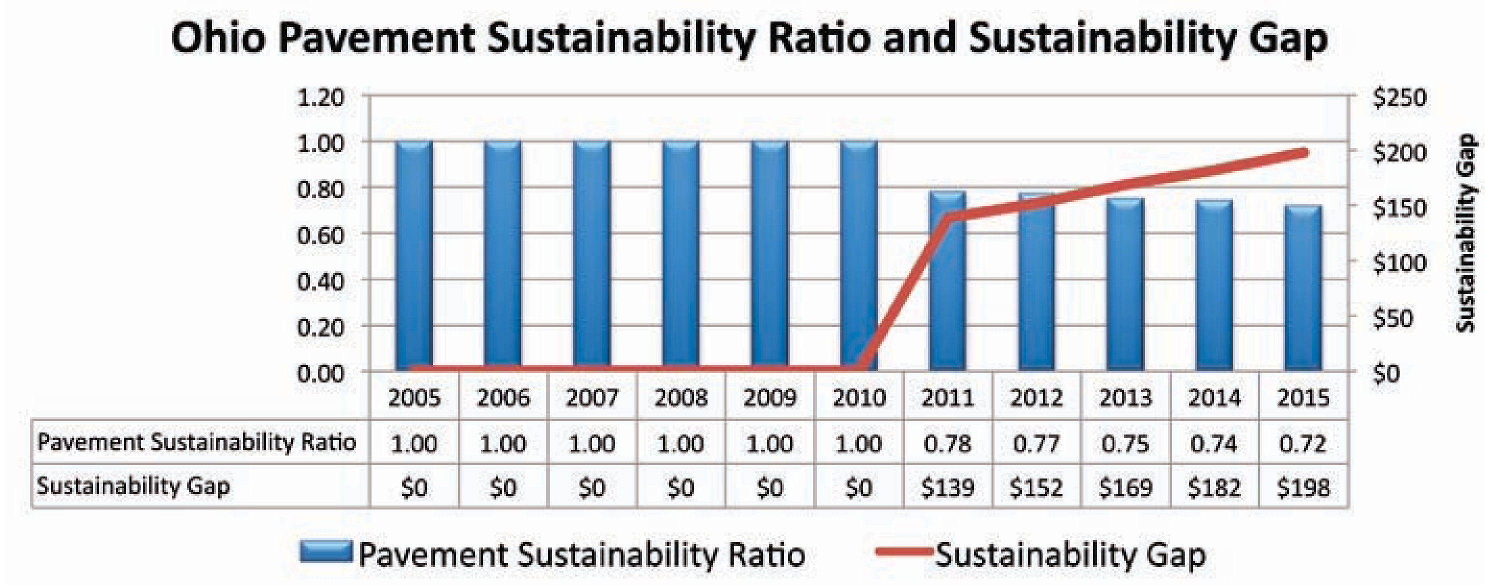


FIGURE 19. *Ohio pavement sustainability ratio and gap.*

Table 13. *Ohio pavement expenditures and outcomes.*

Ohio Pavement Expenditure (Actual and Forecast) 2010-2012 Business Plan										
Pavement Preservation Program	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Pavement Preservation Budget	$ 581	$ 578	$ 484	$ 612	$ 676	$ 674	$ 709	$ 742	$ 776	$ 812
Priority System Acceptable	98%	98%	98%	98%	97%	98%	98%	97%	97%	96%
General System Acceptable	95%	96%	96%	96%	96%	95%	95%	94%	92%	88%
Urban System Acceptable	97%	98%	98%	98%	97%	97%	97%	96%	94%	91%
(expenditures in $millions)										

Table 14. *Increased investment and achievement of asset goals.*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PSR Based on 2006 Pavement Budget	1.00	1.00	1.00	1.00	1.00	1.00	0.78	0.77	0.75	0.74	0.72		
PSR Based on 2010 Budget	1	1	1	0.91	0.96	1.18	1.04	0.97	1.00	0.98	0.96	1	1
Expenditure Delta	$0	$0	$0	$0	$0	$0	$139	$152	$167	$182	$198	$260	$296
(in $millions)													

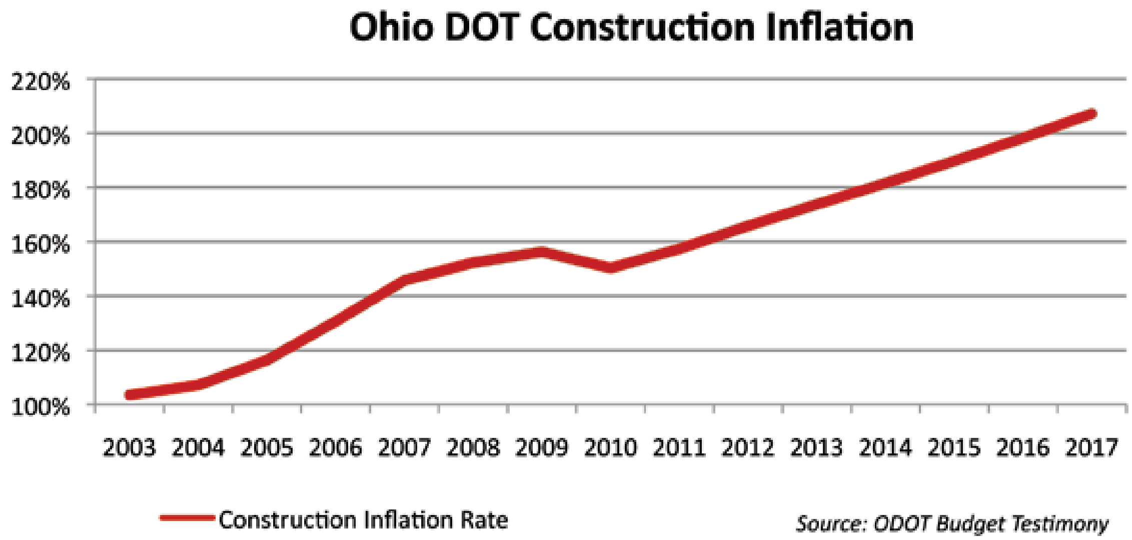


Figure 20. *Construction inflation influenced investment needs.*

Utah Pavement Sustainability Ratio Computation

In another example, the report generates a Pavement Sustainability Ratio using data from the Utah Department of Transportation (UDOT).

UDOT is considered to be one of the agencies with leading asset management processes and practices. As such, it provides the type of sophisticated long-term asset management forecast necessary to generate a credible Pavement Sustainability Ratio. The agency has a mature asset management approach that includes systematic and cost-effective maintenance, preservation, rehabilitation and operation of its physical assets. The UDOT Transportation Asset Management (TAM) approach tries to efficiently balance budget constraints, national issues, environmental priorities and public expectations in aligning its practices and applying asset management principles. With approximately 6775 center lane miles (CLM) of roadway network to manage, the agency has successfully combined engineering, economics and sound financial planning with sound business practices in its decision-making.

To efficiently prioritize and manage its network the DOT has categorized the road network into four tiers based on the Annual Average Daily Traffic (AADT).

The four tiers/categories are:

- Interstate Highways
- Level 1 NHS > 2,000 AADT
- Level 1 Non NHS > 2,000 AADT
- Level 2 < 2,000 AADT (mostly non-NHS)

These four tiers are sometimes combined for analysis purposes into three related categories, the Interstate, NHS and Non-NHS.

UDOT uses several factors (Condition Indices) to track the overall condition and performance of the roads. The Overall Condition Index (OCI) is the average of four primary Condition Indices. For asphalt, these are Ride, Rut, Environmental Cracking and Wheel Path Cracking. For concrete, these are Ride, Joint Faulting, Joint Spalling and Slab Cracking.

The agency has a strategy of "Good Roads Cost Less" (GRCL). Some of the interstate and level 1 road sections/segments have deteriorated to a state where they need minor and major rehabilitation. These roads will be managed on a "worst first" basis and are kept in serviceable condition through "Band-Aid" treatments until they can be reconstructed. However, the agency focuses on preservation of the roads that are in good condition to ensure that they continue to be in good condition. The preservation focus is to take care of the system to ensure sustaining its condition as "good" for the long-term.

UDOT has a strategic approach to financial planning as well as to engineering and implementation to address the long-term performance and sustainability of transportation assets. The strategy includes designing perpetual pavements on new capacity and pavement reconstruction projects. The agency defines perpetual pavement as "a pavement designed for a 50 year structural life, which will require a program of surface seals at set intervals throughout that 50 year life of the pavement. A perpetual pavement should not require any major rehabilitation or reconstruction work for the life of the pavement."

UDOT's preservation treatment includes corrective maintenance, routine maintenance, preventive maintenance and minor rehabilitation. Corrective maintenance addresses immediate concerns of safety or pavement integrity and restores the pavement from unforeseen conditions to serviceable levels. Routine maintenance involves proactive day-to-day activity to maintain and preserve pavement conditions at satisfactory levels. Preventive maintenance involves improving functional pavement conditions and extending the service life of the pavement. These are normally done on the surfaces of structurally sound pavements in good to fair condition and are lower-cost time-based treatments. The DOT's rehabilitation improves the pavement structure and addresses structural enhancements that extend service life or improve load-carrying capacity. Minor rehabilitation mainly addresses functional restoration of pavement surfaces due to age related environmental cracking. Major rehabilitation usually increases pavement thickness to increase strength, addresses structural enhancements and accommodates increased traffic loading. Reconstruction replaces the entire existing pavement structure with similar or increased pavement thickness, thereby addressing pavements that have failed, become obsolete or have subgrade issues.

In general, UDOT has put in place practices that help long-term sustainability of its transportation assets. These practices involve doing a Structural Overlay and Surface Seal in the 15th and 30th year. In between these two, alternate treatments of Surface Seal and Surface Rejuvenation are done every 3 years to sustain the condition of the pavement for 50 years.

Trade-offs and System Conditions

The historic trend of UDOT's pavement conditions are as shown in Figure 21 below:

Figure 21 shows that the Overall Condition Index of the network is falling from 89.3 in 2004 to 76.5 in 2010. The number of center lane miles in "poor" condition is increasing from 3.73 in 2004 to 146.97 in 2010.

Agencies are currently challenged with making the right decisions on where to invest and how much to invest in their transportation assets. With limited funds, priorities will have to established and tradeoffs will have to be made, both across asset categories as well as within asset categories. Under such circumstances, some assets will suffer from underinvestment. The goal is to ensure long-term sustainable management and maintenance of the transportation assets and therefore, to ensure that any under-investment occurs in areas of least

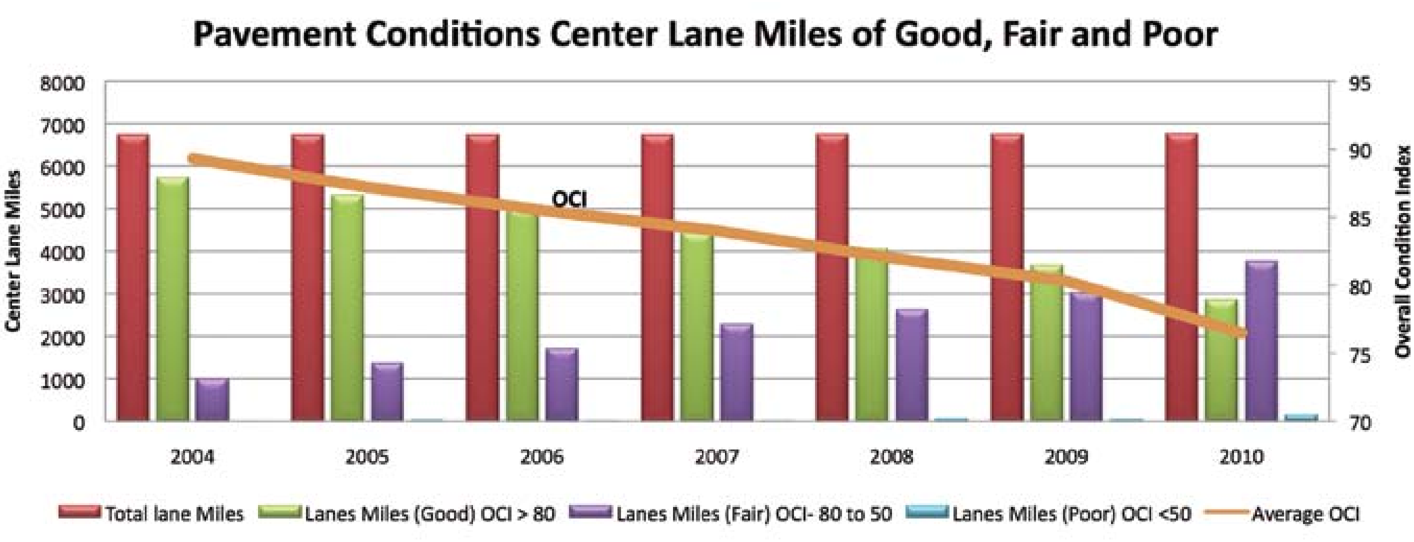


Figure 21. *Utah pavement conditions over time.*

impact. Under investment, if applied selectively, may result in poorer condition and performance of some of the assets or if applied across the board, can result in poorer conditions even for high-priority assets. The computation of a Pavement Sustainability Ratio quantifies and brings to the forefront the projected results based on anticipated investment levels. It facilitates and triggers objective trade-off decisions and helps in better financial planning with the goal of making optimal use of available funds.

The discussion below focuses on the condition of the roadway network as well as budgets available and required to manage and maintain optimal pavement conditions. The information is used to compute a Utah PSR.

Figure 22 shows the Overall System Condition (OCI) of the different tiers of the roadway network based on projected funding for years from 2012 to 2030.

The figure shows the Overall System Condition (OCI) index falling from 74.72 in 2012 to 61.4 in 2030. Figure 22 also shows the OCI for the different tiers of roads in Utah. In the trade-off required by the budget constraints, the different priorities assigned to the three tiers (Interstate, NHS and Non-NHS) of the system are reflected in the difference in the condition of these tiers for the analysis period.

The condition for the Interstate system drops from an OCI of 87.0 in 2012 to an OCI of 83.6 in 2030, the condition for the NHS drops from an OCI of 80.04 in 2012 to an OCI of 74.94 in 2030 and the condition index for the non-NHS drops from an OCI of 71.13 in 2012 to an OCI of 46.16 in 2030.

Figure 22 also shows how the agency is using the available budgets and making trade-offs in managing and maintaining the performance and condition of the roadway network. The approach used gives higher priority to the more heavily used roads and to those carrying heavier loads as compared to those that have lesser traffic and carry lighter loads.

The highest priority is being given to the Interstate system. Second priority is given to the NHS system that is more used than the non-NHS. The third priority is given to non-NHS, the lesser used of the three systems.

Trade-offs and Backlogs

Another way to depict the long-term consequences or outcomes of investment decisions is to measure backlogs of needed treatment.

Backlog is the term being used in this document for the roadway sections that require treatment but do not receive maintenance or rehabilitation activity.

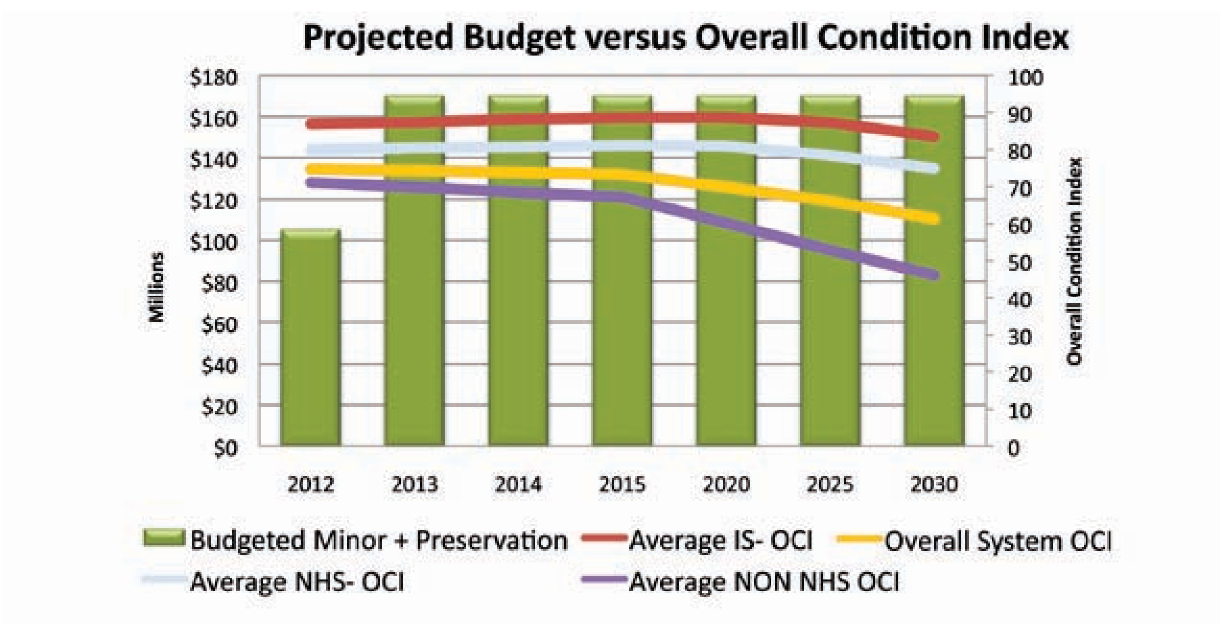
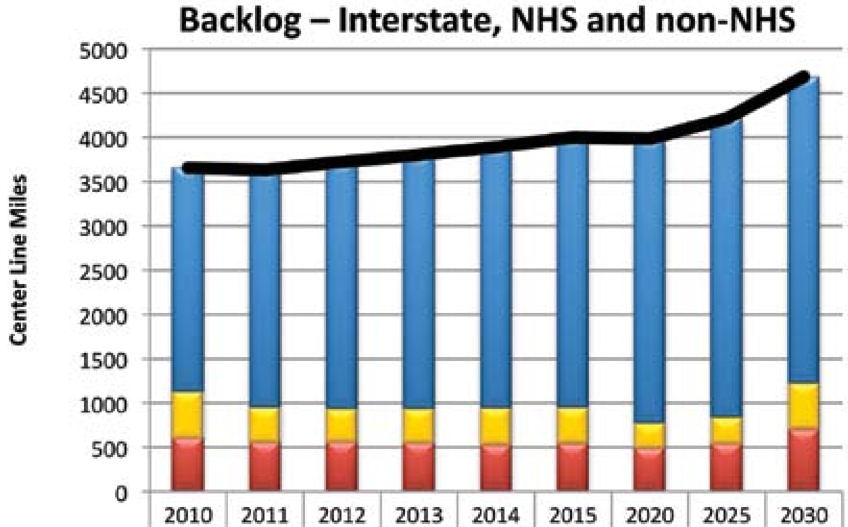


Figure 22. *Utah pavement budget versus condition.*



	2010	2011	2012	2013	2014	2015	2020	2025	2030
Non-NHS CLM (No Work Done)	2529	2684	2790	2867	2947	3054	3213	3380	3464
Interstate CLM (No Work Done)	523	392	371	385	415	401	280	292	519
NHS CLM (No Work Done)	602	555	559	548	528	544	492	541	701
Total CLM In Backlog	3655	3632	3722	3802	3892	4000	3986	4214	4684

Figure 23. *Backlog of pavement treatments.*

Figure 23 shows the backlog of Interstate, NHS and non-NHS systems for the period starting in 2012 through 2030. When there are fewer constraints with availability of funds by moving funds across the different fund categories, agencies can be more liberal in performing preservation and maintenance activities on all tiers of pavements. As funds become more limited, ensuring sustainable performance-based management of assets requires prioritizing and making trade-offs between how much to spend and when to spend monies on the Interstate, NHS and non-NHS system.

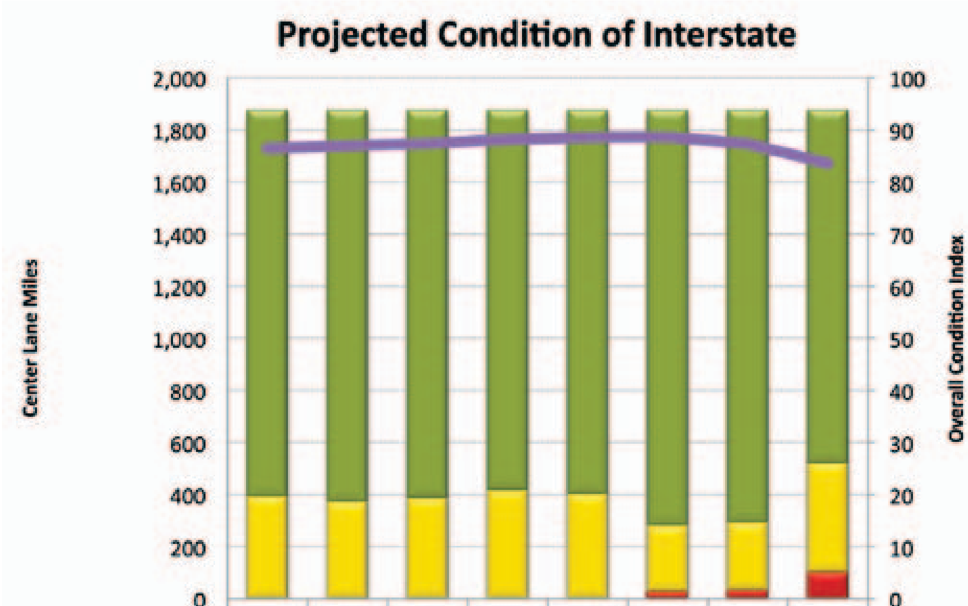
Figure 23 shows that the backlog on the Interstate system is being kept to a minimum, the backlog on the NHS is higher and the backlog of miles not addressed by maintenance and rehabilitation activity in the non-NHS system increases from 2,530 CLM in 2012 to 3,456 CLM in 2030. Figure 23 also shows that the total backlog increases from 3,655 CLM in 2012 to 4,685 CLM in 2030.

Figure 24 shows the condition of the interstate system after trade-offs have been applied to optimize the use of available funds. It shows that the Interstate in "good" condition increases from 1,481 CLM in year 2011 to 1,503 CLM in 2012. The overall CLM for interstate in "good" condition varies minimally between 1,490 CLM and 1,450 from 2013 through 2015. The CLM in "good" condition increases from 2020 through 2025. In 2030 the CLM in "good" condition decreases while the CLM in "poor" condition increases.

Figure 24 also shows the corresponding change in the average OCI for the interstate system from year 2011 to 2030. It shows the OCI for the interstate system improving from 86.48 in year 2011 to 88.63 in year 2020. Figure 24 also shows that the projected OCI drops to 83.57 in 2030.

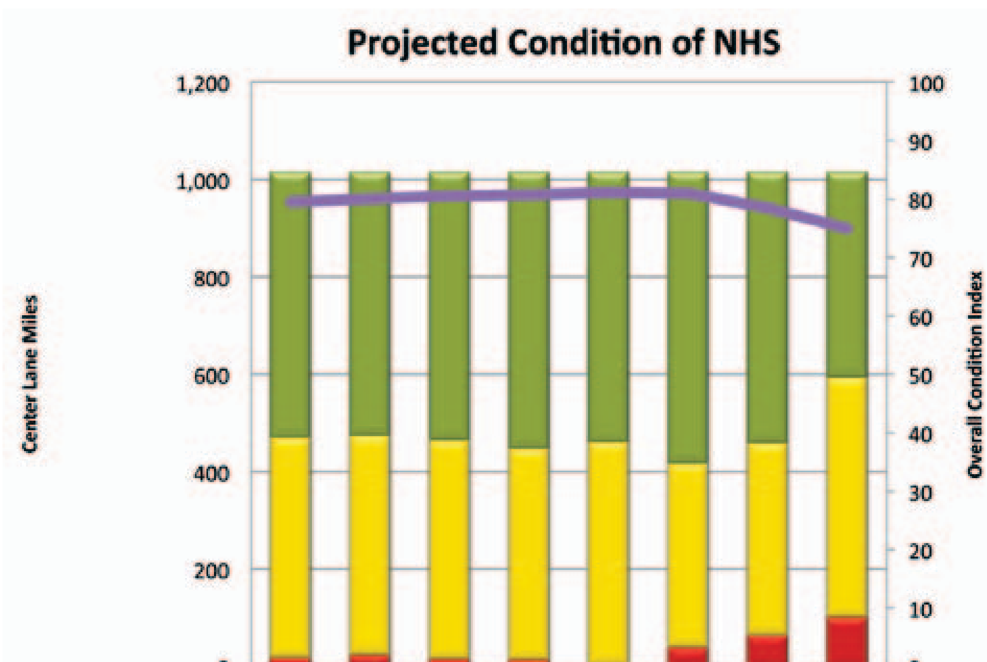
Figure 25 shows the number of CLM for the NHS from 2011 to 2030 in "good", "fair" and "poor" condition. It also shows the statewide average OCI improving from 79.47 in year 2011 to 80.04 in year 2012 and remaining around 80 from year 2012 through year 2020 and then dropping progressively to 74.94 by 2030.

Figure 26 shows the condition of the non-NHS in "good", "fair" and "poor" from 2011 through 2030. It shows the CLM in "fair" condition decreasing from 2635 in year 2011 to 1103 in year 2030. It shows a corresponding increase in the "poor" condition for the same period with CLM of "poor" condition increasing from 155.2 to 2526.9. The figure also shows the number of CLM in "good" condition decreasing from 1059 in year 2011 to 219 in year 2030. This overall fall in system condition is reflected in the OCI decreasing from 72.3 in 2011 to an OCI of 46.165.



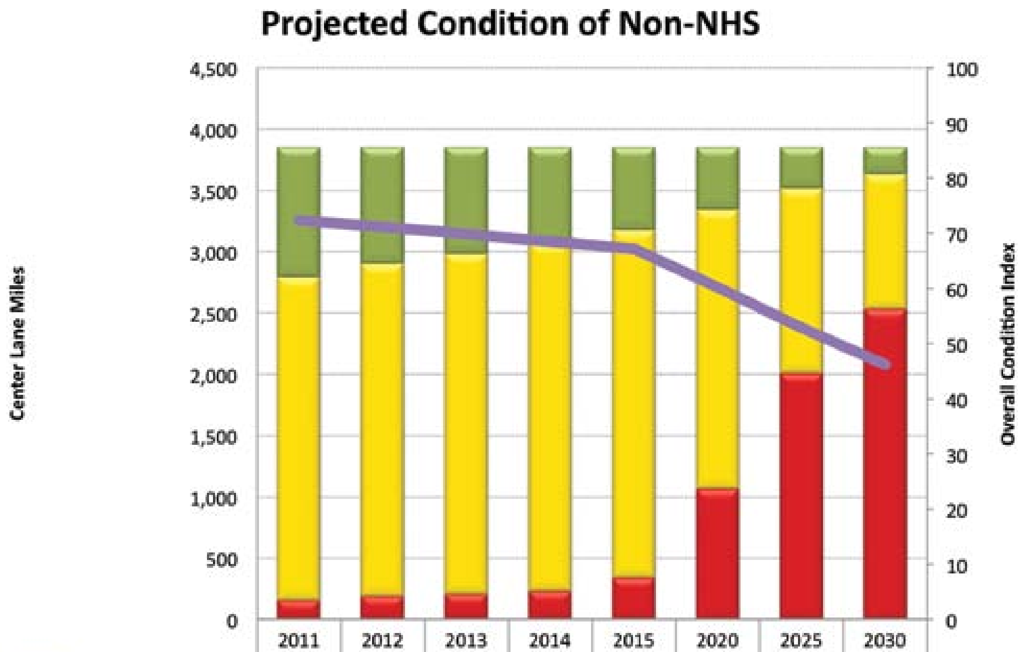
	2,011	2,012	2,013	2,014	2,015	2,020	2,025	2,030
IS-Good	1482	1503	1488	1459	1473	1594	1582	1355
IS-Fair	393	372	387	416	402	254	260	420
IS -Poor	0.0	0.0	0.0	0.0	0.0	27.6	33.0	100.2
Average IS- OCI	86.48	86.96	87.36	88.19	88.58	88.63	87.34	83.57

Figure 24. *Utah Interstate pavement condition trends.*



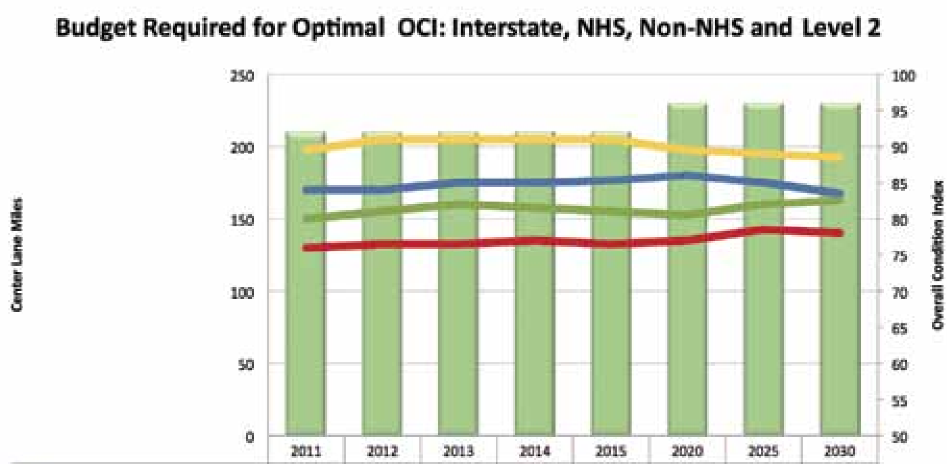
	2011	2012	2013	2014	2015	2020	2025	2030
NHS-Good	545	542	551	568	554	599	557	422
NHS-Fair	451	450	448	433	457	377	394	492
NHS-Poor	18	24	16	14	3	40	64	100
Average NHS- OCI	79	80	81	81	81	81	78	75

Figure 25. *NHS conditions and trends.*



	2011	2012	2013	2014	2015	2020	2025	2030
Non NHS-Good	1059.6	948.6	868.9	785.5	674.3	509.0	336.1	219.35
Non NHS-Fair	2635.2	2713.2	2775.0	2833.3	2837.0	2277.5	1509.4	1103.78
Non NHS-Poor	155.2	188.2	206.1	231.2	338.7	1063.5	2004.5	2526.9
Average NON NHS OCI	72.337	71.134	69.859	68.480	67.187	60.188	52.863	46.165

Figure 26. *Non-NHS pavement projections.*



	2011	2012	2013	2014	2015	2020	2025	2030
Required Dollars (M)	210	210	210	210	210	230	230	230
Optimal OCI - IS	89.5	91	91	91	91	89.5	89	88.5
Optimal OCI- Level 1-NHS	84	84	85	85	85.3	86	85	83.5
Optimal OCI- Level 1 Non-NHS OCI	80	81	82	81.5	81	80.5	82	82.5
Optimal OCI: Level 2	76	76.5	76.5	77	76.5	77	78.5	78

Figure 27. *Budget need for optimal conditions.*

Computing Long-Term Optimum System Conditions

Figure 27 shows the optimal long-term conditions that can be achieved for the Interstate System (IS), NHS and non-NHS systems and the budget required to sustain the optimal OCI for the system from 2011 through 2030, assuming that there are no budget constraints.

Figure 27 shows how with appropriate long-term financial planning an agency can compute the optimal amount of funds required to sustain the long-term performance and condition of the roadway network.

To identify the optimal conditions that can be achieved for a long-term period of nearly 20 years in the future, different scenarios of conditions that can be achieved for different budget amounts for each tier of the roadway are generated. These multiple scenarios are then analyzed to identify the minimum budget amount required to achieve and sustain optimal pavement conditions in the future.

Figure 27 shows the optimal condition that can be achieved for each of the tiers of the roadway. The total annual amount required to sustain the optimal OCI is approximately $210 million in years 2110 through 2015. The budget required to sustain the optimal OCI beyond year 2015 increases to $230 million dollars annually.

Utah DOT—The Pavement Sustainability Ratio

The available and required budgets (for optimum OCI) as discussed above are consolidated in Figure 28 along with the budget deficit to maintain optimum conditions. Figure 28 also depicts the Goal PSR (assuming optimum budget availability) as well as the projected PSR based on available budgets.

A Pavement Sustainability Ratio is a metric calculated by dividing the amount budgeted for pavement maintenance and preservation over time by the amount needed to achieve a specific pavement condition target.

This PSR= 1 is shown in purple in Figure 28. The PSR is computed as:

$$\frac{\text{Pavement Budget}}{\text{Pavement Needs}} = \text{Pavement Sustainability Ratio}$$

Figure 28 shows the currently projected PSR based on available budgets in orange. The PSR is 0.4 in 2012, showing a 60 percent shortfall from optimum needs. It increases to 0.8 in 2013 and remains at 0.8 until 2015. After 2015, the PSR drops from 0.8 to 0.74 in 2020 and remains at 0.74 through year 2030.

As shown in the UDOT example, a Pavement Sustainability Ratio can be computed using the asset condition forecasts and related investment needs

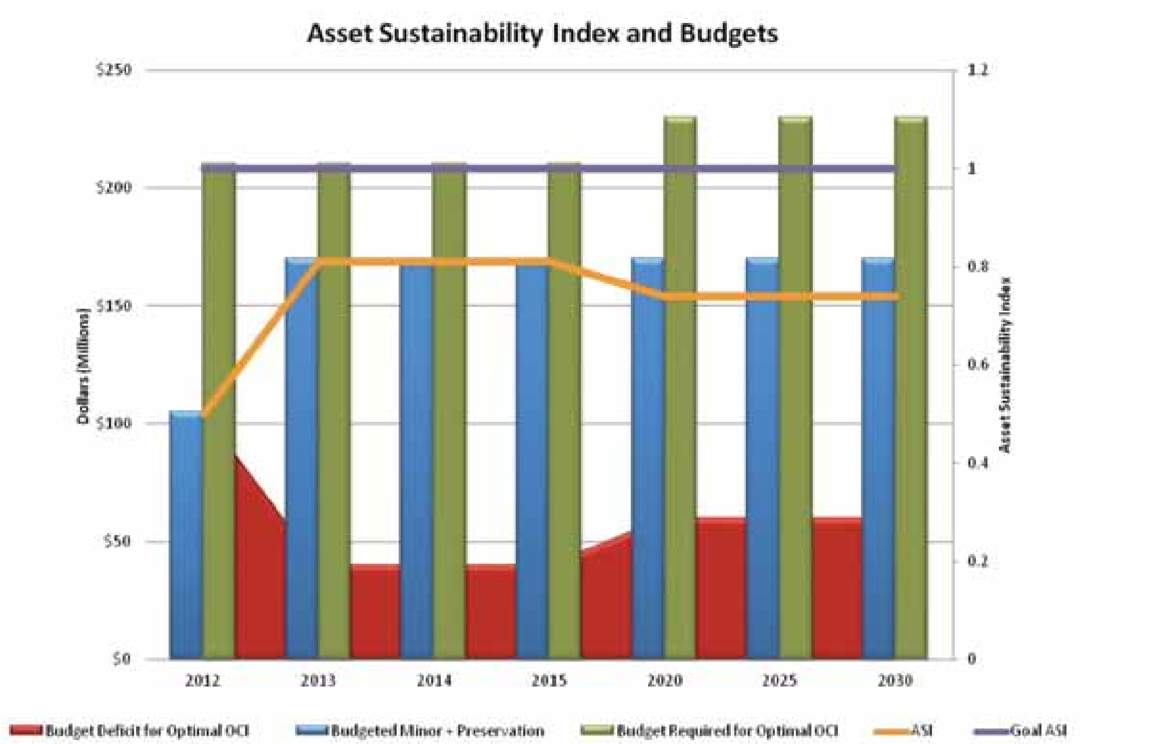


Figure 28. *Utah pavement sustainability ratio.*

generated from a mature U.S. State asset management process. The example also illustrates that the PSR thus is a tool that can be effectively used to consolidate the analysis of the overall system conditions, required budgets to maintain optimum system conditions, and available budgets (representing fiscal constraints) into a single metric. The PSR can therefore also be used to effectively illustrate and communicate to all stakeholders the budget status and investment needs required to maintain optimum system conditions.

Minnesota Pavement Sustainability Example

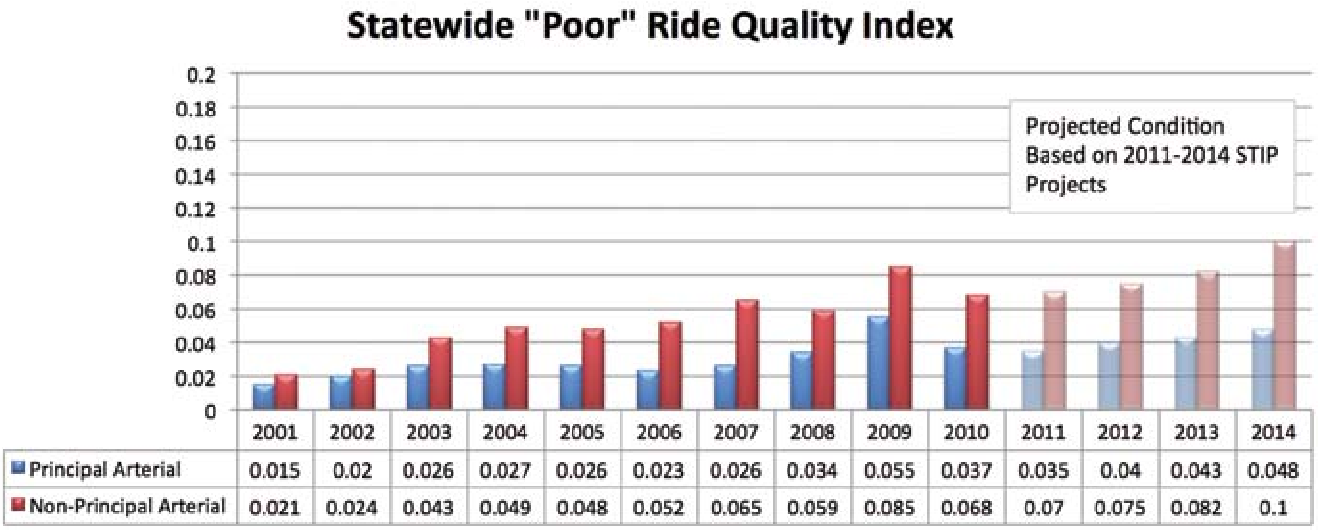
This example illustrates how a Pavement Sustainability Ratio could be calculated using a third State's data. This analysis also illustrates how long-term system forecasts can be used to illustrate the consequences of tradeoffs.

Figures 29 (below), 30 and 31 (see next page) from the Minnesota DOT (MnDOT) are typical of the type of information that often is portrayed by States and which could contribute directly to a Pavement Sustainability Ratio. Figure 29 illustrates that the agency has struggled since 2001 to reach its pavement condition targets and that it has had to accept gradually lowering conditions, particularly on its Non-Principal Arterials. Figure 30 illustrates that the percentage of "Poor" Ride Quality Index miles also has steadily increased and are forecast to rise significantly in the next four years. Even more germane to the concept of an Asset Sustainability Index is Figure 31. It illustrates that the Remaining Service Life of the State's pavements has steadily declined, by as much as 43 percent between 2001 and 2010 for the Non-Principal Arterials. Figures 30 and 31 illustrate the type of long-term implications that GASB 34 and TAM guidelines seek to capture. Those figures show the erosion in the "robustness" of the pavement inventory. With its significantly reduced Remaining Service Life, the pavements have less "elasticity" to sustain a temporary budget reduction, to withstand increased traffic loadings or other impacts. In addition, future costs likely will rise as it is more expensive to rehabilitate a deteriorated pavement than to maintain a good one. As such, the "value" of the 2014 pavement inventory is significantly less than the value of the 2001 inventory that had a greater Remaining Service Life. In simple terms, it would be analogous to the value of a car with 50,000 miles compared to one with 71,500 miles, or 43 percent more miles.

Minnesota defines Remaining Service Life as the number or remaining years until a pavement declines to a 2.5 out of 5 in its Ride Quality Index. The rating of 2.5 indicates the pavement is in need of rehabilitation to provide an acceptable ride. The

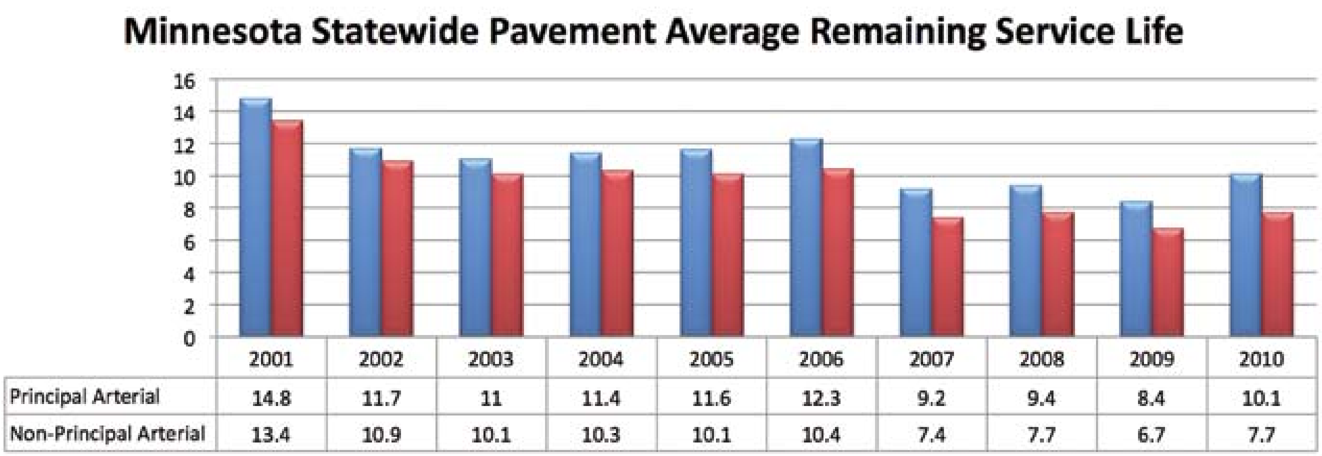
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Principal Arterial	0.767	0.72	0.636	0.634	0.668	0.689	0.663	0.67	0.637	0.702	0.698	0.695	0.688	0.689
Non-Principal Arterial	0.703	0.648	0.553	0.559	0.601	0.611	0.591	0.602	0.553	0.598	0.59	0.601	0.597	0.578
Non-Principal Arterial Target	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Principal Arterial Target	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Figure 29. *MnDOT "good" ride quality.*



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Principal Arterial	0.015	0.02	0.026	0.027	0.026	0.023	0.026	0.034	0.055	0.037	0.035	0.04	0.043	0.048
Non-Principal Arterial	0.021	0.024	0.043	0.049	0.048	0.052	0.065	0.059	0.085	0.068	0.07	0.075	0.082	0.1

Figure 30. *MnDOT "poor" ride quality index.*



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Principal Arterial	14.8	11.7	11	11.4	11.6	12.3	9.2	9.4	8.4	10.1
Non-Principal Arterial	13.4	10.9	10.1	10.3	10.1	10.4	7.4	7.7	6.7	7.7

Figure 31. *MnDOT remaining service life.*

terminal condition of 2.5 does not indicate the road is unusable, only that its condition cannot be restored without significant rehabilitation.

Minnesota's data and its analyses clearly inform policy makers of the pavement-deterioration trends and their causes. The first important trend is declining overall revenue forecasts.

As Figure 32 illustrates, capital revenue forecasts decline substantially as fuel tax receipts stagnate, operating costs rise, less bond income can be afforded and Federal apportionments remain unclear.

Figure 33 illustrates that commensurate with the overall decline in spending, pavement expenditures will fall. This decrease in pavement spending comes at a time of enhanced investment in bridges, following the collapse of the I-35 Bridge in Minneapolis. A special legislative directive requires the department to replace 120 fracture critical or structurally deficient bridges. Approximately 32 percent of all STIP funding from 2011 to 2020 will be devoted to bridges, with two-thirds of that devoted to these structures.[7] The results are predicted to be that the percentage of bridges meeting their structural condition goals will rise from 87 percent in 2009 to 89 percent in 2014, with conditions through 2020 projected to remain above the target of 84 percent.

MnDOT predicts that it will meet several important long-term targets in the 2011–2020 planning period. Targets it expects to meet include:

- All 120 fracture critical or structurally deficient bridges will be repaired or replaced by 2018;
- Statewide structural conditions for all bridges will be met;
- Road fatalities are forecast to decline.

However, the expected lower revenue and investment-tradeoff decisions will result in the

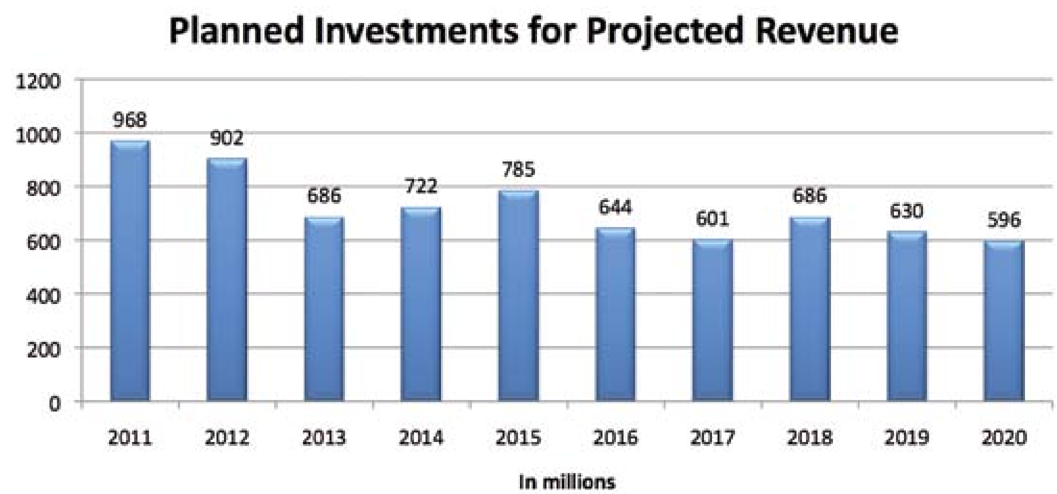
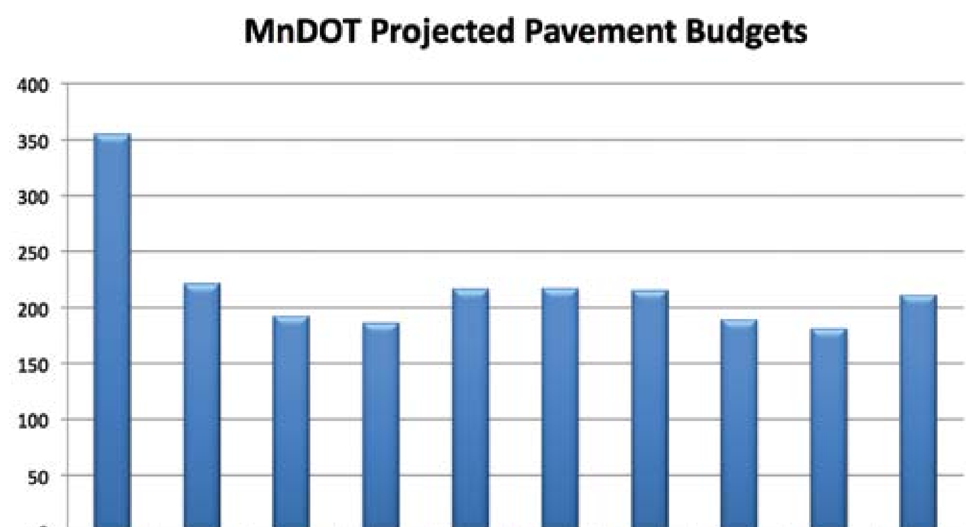


Figure 32. *MnDOT declining program projections.*



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pavement Budgets	355	221	192	186	216	217	215	189	181	211

Figure 33. *MnDOT's declining pavement investment levels.*

department being unable to meet its pavement targets particularly on the Non-Principal Arterials. The number of State highway miles with good pavement conditions will decrease and the number of State highway miles with poor pavement condition will increase from 990 miles in 2009 to 2,528 by 2019.

The estimated cost of the needed investment to sustain the Minnesota pavement conditions was not directly available for this report. At the time of publication, MnDOT was preparing public involvement efforts for an updated long-range capital program. The type of data presented above for MnDOT pavements led to a significant review of long-term allocations and a proposed adjustment of program amounts to address long-term pavement needs.

CHAPTER 5

U.S. Examples of a Bridge Sustainability Ratio

This chapter uses bridge condition and expenditure data from the Ohio, North Carolina and Minnesota DOTs to illustrate a Bridge Sustainability Ratio.

Ohio DOT Bridge Sustainability Ratio

A review of the department's bridge analysis and investment over two decades allows the illustration of how Asset Sustainability metrics can be used to sustain acceptable bridge conditions, make tradeoff analyses and optimize investment into the highest asset priorities. The following analysis tracks ODOT bridge condition and budgets from 1997 to 2017. Although Ohio does not use metrics called "sustainability" metrics, it uses data that can provide inputs for sustainability metrics. It also operates under a philosophy of sustaining a "steady state" of high and continuously attained asset conditions. Those concepts are quite similar to the sustainability concepts discussed in this report.

ODOT manages approximately 14,000 bridges out of a total statewide inventory of more than 28,000 bridges over 20 feet in length. Ohio defines a bridge as a structure greater than 10 feet in length. By its definition, 42,000 bridges are managed statewide. As a "Home Rule" State, the majority of Ohio bridges are locally managed, although ODOT is responsible for approximately two-thirds of the State's total bridge area. The Ohio DOT manages the nation's fifth largest bridge inventory, according to data from the National Bridge Inventory. Overall, it has the 14th highest percentage of total deficiencies in its entire statewide bridge inventory when both structural deficiencies and functional obsolescence are considered for all bridges, including local ones. However, the DOT has focused on its major bridges and when the National Highway System bridges are examined, Ohio's structural deficiencies on that system are the 28th lowest nationally.

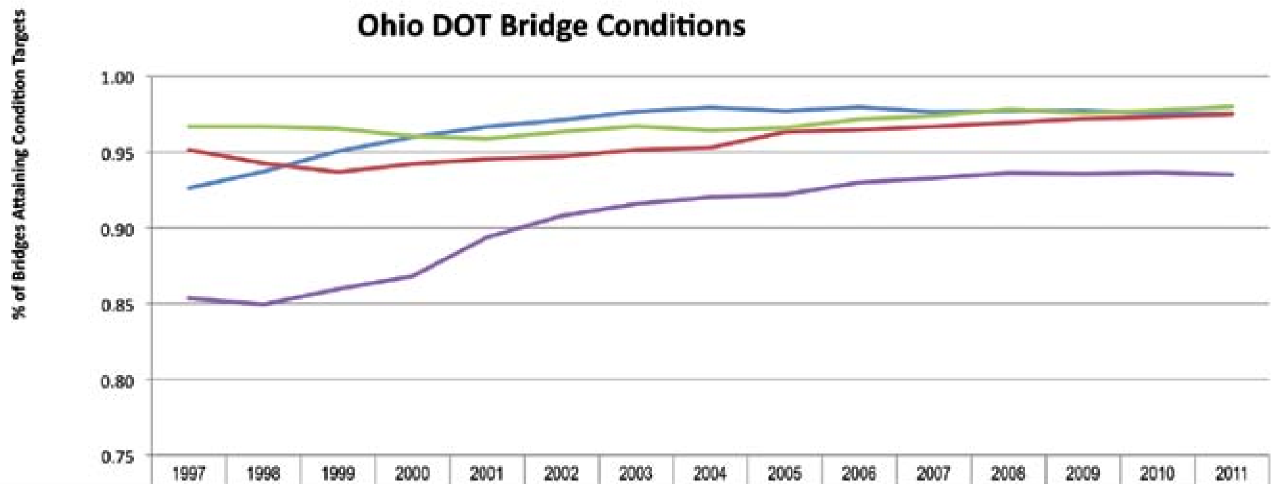
As can be seen in Figure 34 (see next page), the ODOT manages its bridge inventory through four primary rating categories which are:

- **General Appraisal**—A composite of the substructure and superstructure condition, except for the deck or floor.
- **Floor Condition**—The roadway portion of a bridge, including shoulders.
- **Wearing Surface**—The topmost layer of material applied upon a roadway to receive the traffic loads and to resist the resulting disintegrating action; also known as wearing course.
- **Paint Condition**—As is self-evident, this relates to the quality of the paint condition.

Calibrating Budgets for Asset Sustainability

The following section discusses how over a number of years the department calculated and periodically updated its analysis of conditions and needed budgets in order to sustain its bridges at its targeted level. This section examines estimates and budget allocations in 2006, 2008, 2010 and a pending update in 2011. Each update recalibrated conditions and needed budgets during a volatile period when unit prices changed significantly and long-term funding was uncertain.

In its 2006 biennial business plan the department published the following high-level summary of expenditures and conditions that serve as a de facto Bridge Sustainability Ratio input. As shown in Table 15, budgets for bridge preservation ranged from $221 million in 2005 to a projected peak in 2010 of $258 million and subsequent decline again



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
General Appraisal	0.93	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Floor Condition	0.95	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97
Wearing Surface	0.97	0.97	0.97	0.96	0.96	0.96	0.97	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98
Paint Condition	0.85	0.85	0.86	0.87	0.89	0.91	0.92	0.92	0.92	0.93	0.93	0.94	0.94	0.94	0.94

Figure 34. *Ohio bridge conditions over time.*

through 2015. The line of "% General Appraisal Acceptable" illustrates ODOT forecast that 98 percent of its bridge inventory would meet its general appraisal goal through 2010 falling to 97 percent after 2012. The Projected Shortfall illustrates the amount of deficit ODOT predicted in 2006 would be experienced if inflation in 2006 continued at the high rate it was experiencing at that time. The shortfall equates to what this report calls the Sustainability Gap. As shown in Table 15, that gap totaled $232 million from 2011–2015.

These numbers allow a Bridge Sustainability Ratio to be developed for the period 2005–2015 as shown in Table 16.

As the department did with its earlier pavement shortfall, it revisited its forecasts in its 2008 Business Plan and again in its 2010 Business Plan update. Those updates showed that inflation had cooled from a high of more than 12 percent to between 4 and 5 percent. Despite slowing, the rise in material costs still required additional investment

Table 15. *Ohio bridge expenditures, funding gap.*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Bridge Preservation Budget	$141	$141	$170	$179	$187	$197	$145	$147	$148	$150	$151	$1,756
Major Bridge	$80	$117	$ 60	$ 60	$ 61	$ 61	$ 62	$ 62	$ 63	$ 64	$ 64	$754
Total	$221	$258	$230	$239	$248	$258	$207	$209	$211	$214	$215	$2,510
% Gen. Appraisal Acceptable				98%		98%		97%			97%	
Projected Shortfall or Sustainability Gap							($48)	($52)	($58)	($34)	($40)	($232)

Table 16. *Ohio bridge sustainability ratio components.*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Bridge Budget	$221	$258	$230	$239	$248	$258	$207	$209	$211	$214	$215	$2,510
Bridge Need	$221	$258	$230	$239	$248	$258	$255	$261	$269	$248	$255	$2,742
Bridge Sustainabilty Ratio	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.8	0.9	0.8	
Sustainabiilty Gap	$0	$0	$0	$0	$0	$0	-$48	-$52	-$58	-$34	-$40	-$232
($millions)												

to sustain conditions. As a result as shown in Table 17, ODOT increased bridge investment in its 2008 and its 2010 budget updates. Overall, bridge budgets increased by $468 million over the period of 2008–2015 compared to what had been forecast to be spent during that period in the original 2006 forecast. ODOT sustained its general appraisal conditions at 98 percent acceptable with the additional budgeted amounts and continued the sustainable bridge conditions.

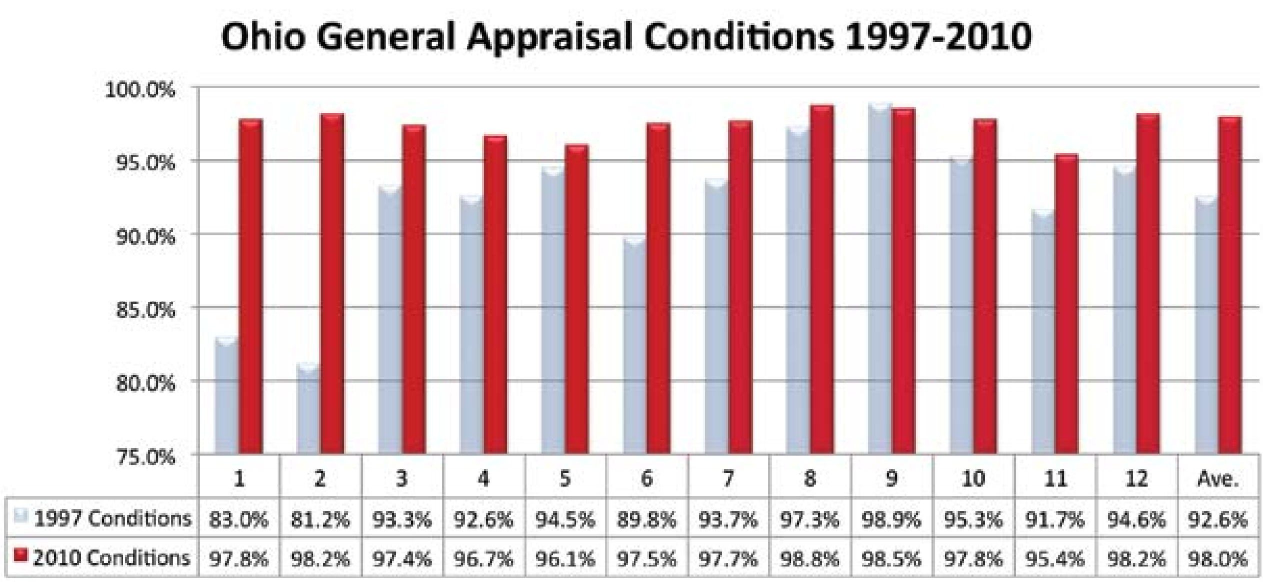
As shown in Table 17, the forecasted conditions indicate that with the higher budgets ODOT will sustain its target which was 98 percent acceptable up through 2007 when it was changed to 96 percent acceptable. ODOT forecast future bridge conditions based upon the programmed projects and its deterioration curves for each of the four categories of condition, General Appraisal, Floors, Wearing Surfaces and Paint.

In the Executive Summary and in Chapter 4, this report discussed how the Asset Sustainability metrics can aid in trade-off analysis. They also can assist with detailed optimization analysis. Resources can be redirected from where there is a ratio greater than 1.0 to assets, or systems or regions where investment is less than 1.0. The type of analysis conducted in Ohio allowed such tradeoffs to occur.

As seen in Figure 35, when ODOT began its asset management process in earnest in 1997, 92.6 percent of its statewide bridge inventory met its General Appraisal target of 5 or greater out of a scale of 0–9. Districts 8 and 9 nearly met the 2010 goal of 98 percent acceptable when the asset management process began in 1997. In 1997, ODOT had a goal of 90 percent of its bridges meeting the General Appraisal target. At that lower goal, nine of the 12 districts met target. Two districts, 1 and 2 were substantially below the target.

Table 17. *Changes in Ohio bridge funding, sustainability ratio.*

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bridge Budget 2010 Business Plan	$258	$230	$254	$262	$227	$270	$277	$313	$325	$341	$358
Difference from 2006			$15	$14	-$31	$63	$68	$102	$111	$126	
Difference from 2008			$7	-$5	-$56	-$17	-$16	-$8	$31	$53	
% Gen. Appraisal Acceptable	0.98	0.98	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
BSR as of 2006 Business Plan	1.00	1.00	1.00	1.00	1.00	0.81	0.80	0.78	0.86	0.84	
BSR as 2010 Business Plan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
All dollars in millions	Actual					Forecast					



	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
1997 Conditions	83.0%	81.2%	93.3%	92.6%	94.5%	89.8%	93.7%	97.3%	98.9%	95.3%	91.7%	94.6%	92.6%
2010 Conditions	97.8%	98.2%	97.4%	96.7%	96.1%	97.5%	97.7%	98.8%	98.5%	97.8%	95.4%	98.2%	98.0%

Figure 35. *General appraisal conditions by district.*

As seen in Figure 36, ODOT achieved a steady improvement in bridge General Appraisal condition between 1997 and 2003 by focusing closely on deficient bridges for improvement and by increasing bridge budgets from $225 million to $256 million, or 14 percent. Bridge condition improvements increased more than did the commensurate increase in spending. Although the percent of bridge area meeting the General Appraisal goal rose from 92.6 percent to 97.5 percent, that represents a 64 percent reduction in the area of structurally deficient bridges. The area of structurally deficient bridges declined from 5.9 million deficient square feet to 1.9 million. This disproportionate improvement occurred because of closely calibrated tradeoffs in which funds were moved from districts and from bridge categories that met target to those that did not. Reductions in expenditures occurred in years such as 2003 when Ohio's Federal apportionment declined because of a budget reconciliation issue and again in 2010 as ODOT wrestled with inflationary pressures. The reductions in bridge allocations in those years were possible because of the relatively robust bridge conditions. Rational tradeoffs could be made and funds could be prioritized for pavements, which were not in as good a condition.

As seen from the condition curve in Figure 36, from 2003 through 2011 Ohio sustained a "steady state" or sustainable bridge inventory condition with a steady and predictable level of investment. Starting in 2012, bridge budgets are to rise steadily to compensate for higher material prices. The State's level of effort in terms of bridge square footage of improvement annually is predicted to remain fairly steady but the unit prices of bridges are predicted to continue a slow, steady rise of between 4 percent and 5 percent annually. With such an inflation forecast, ODOT can predict and plan for a commensurate increase in bridge investment through 2017 to sustain its bridge inventory conditions.

Calculating a District Bridge Sustainability Ratio to Support Tradeoffs

The asset sustainability metrics are intended to support decision making. They illustrate the magnitude of needed investment and they illustrate probable consequences of current investments at a system-wide level. They also allow "drilling down" into the asset level or regional level to further support decision making, including the making of tradeoffs.

The Ohio process allowed the agency to identify areas of sub-goal performance and under-investment in selected areas of its infrastructure. As mentioned earlier, Floor or Deck conditions are one of the four areas of bridge measurement. As can be seen in Figure 37, state-wide 95 percent of bridges area met the Floor condition target in 1997 but two districts, 4 and 12, were considerably below target. Those districts' Floor conditions worsened to a low point for District 4 in 2001 when more than 20 percent of all of its deck area was deficient. For District 12, nearly 16 percent of its total deck area was deficient.

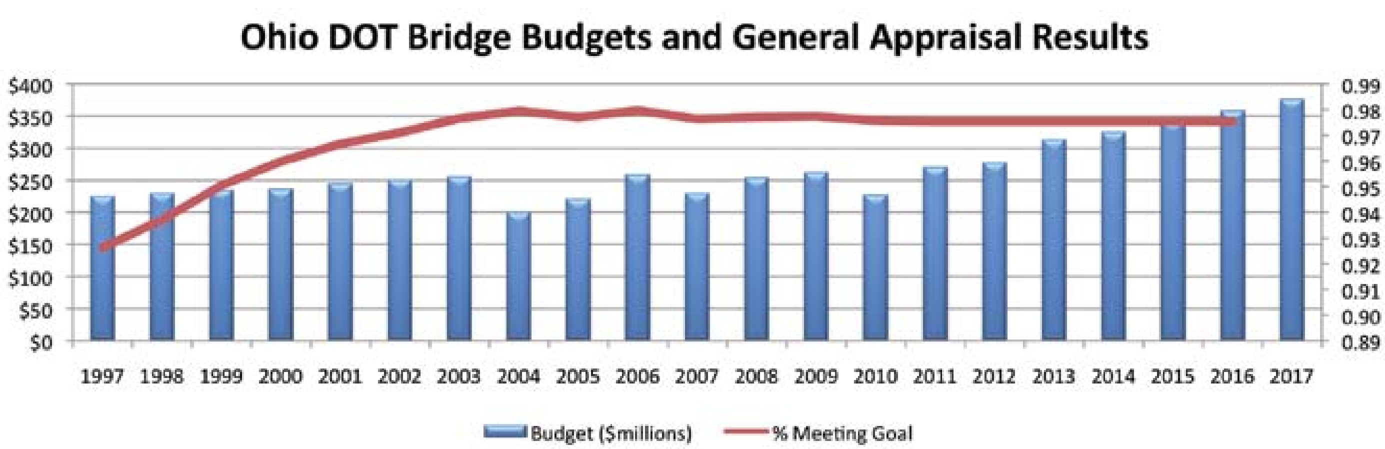
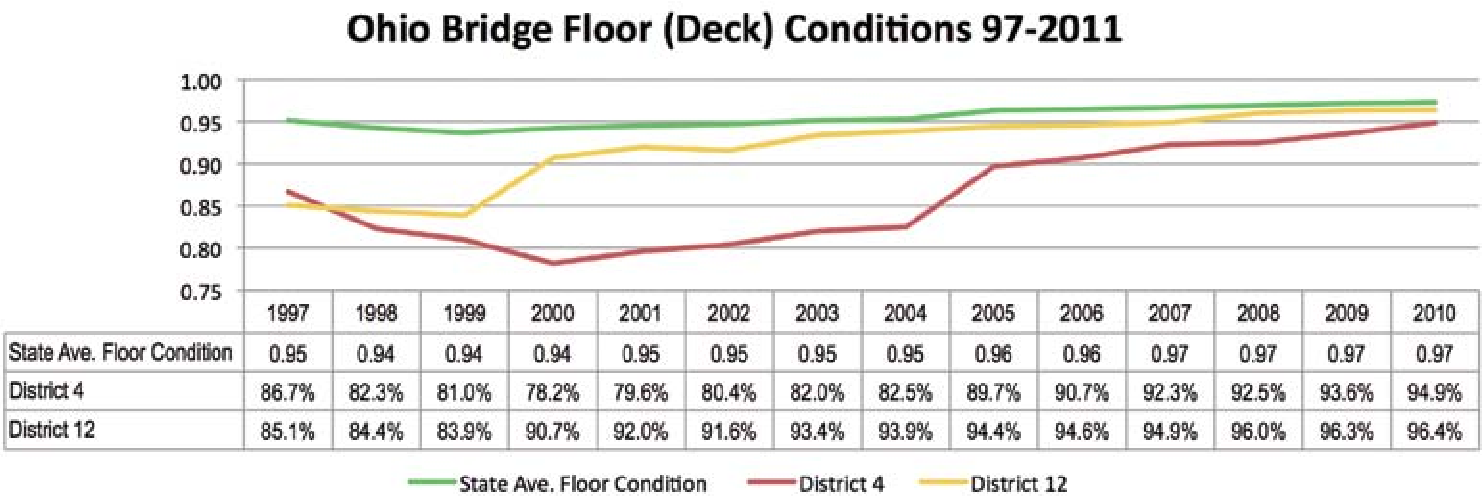


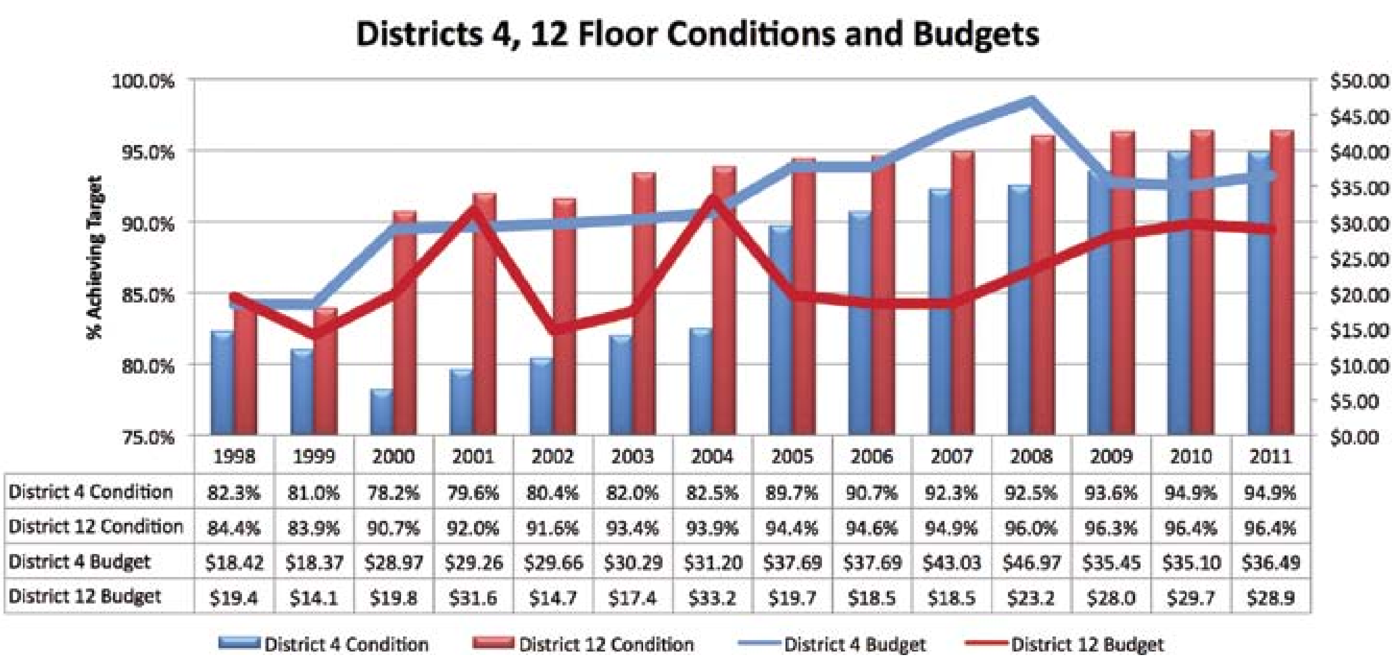
Figure 36. *Statewide bridge condition changes.*

As seen in Figure 38, bridge budgets were increased for both districts along with accountability for targeting deficient bridge floors. District 4's bridge budget rose substantially and with its increased investment it focused upon its floor conditions. The district had the State's third largest bridge inventory and its greatest overall volume of traffic. Its bridge budget grew from a low of $16.9 million in 2000 to a high of $46.4 million in 2001 to "kick start" its bridge improvement effort. The budget varied somewhat year to year but remained more than twice its level from the late 1990s and remains so through the forecast period of 2011. As can be seen, the district's percentage of "Good" Floors rose from a low of 79.6 percent to a high of 94.9 percent by 2010. The statewide goal for 2010 is 96.2 percent acceptable, just above District 4's 2010 condition, as seen in Figure 39 (see next page).



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
State Ave. Floor Condition	0.95	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97
District 4	86.7%	82.3%	81.0%	78.2%	79.6%	80.4%	82.0%	82.5%	89.7%	90.7%	92.3%	92.5%	93.6%	94.9%
District 12	85.1%	84.4%	83.9%	90.7%	92.0%	91.6%	93.4%	93.9%	94.4%	94.6%	94.9%	96.0%	96.3%	96.4%

Figure 37. *Ohio deck condition changes.*



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
District 4 Condition	82.3%	81.0%	78.2%	79.6%	80.4%	82.0%	82.5%	89.7%	90.7%	92.3%	92.5%	93.6%	94.9%	94.9%
District 12 Condition	84.4%	83.9%	90.7%	92.0%	91.6%	93.4%	93.9%	94.4%	94.6%	94.9%	96.0%	96.3%	96.4%	96.4%
District 4 Budget	$18.42	$18.37	$28.97	$29.26	$29.66	$30.29	$31.20	$37.69	$37.69	$43.03	$46.97	$35.45	$35.10	$36.49
District 12 Budget	$19.4	$14.1	$19.8	$31.6	$14.7	$17.4	$33.2	$19.7	$18.5	$18.5	$23.2	$28.0	$29.7	$28.9

Figure 38. *Shifting budgets to address deficiencies.*

To achieve the increase in investment, bridge funds from districts with higher conditions were shifted. In effect, high-performing districts were expected to enter a "preventive maintenance mode" and the extra funds were shifted to the areas of poorer performance. Greater accountability accompanied the increase in funds and districts were given performance metrics to achieve. The intent was not to "reward bad behavior" by giving districts with worse conditions more funds without a commensurate increase in accountability.

The District 4 and District 12 example allows recreation of District Bridge Sustainability Ratios. With Bridge Sustainability Ratios for all 12 districts it would allow ODOT to readily identify, and communicate to decision makers, how funds need to increase or decrease over time among the districts to sustain conditions.

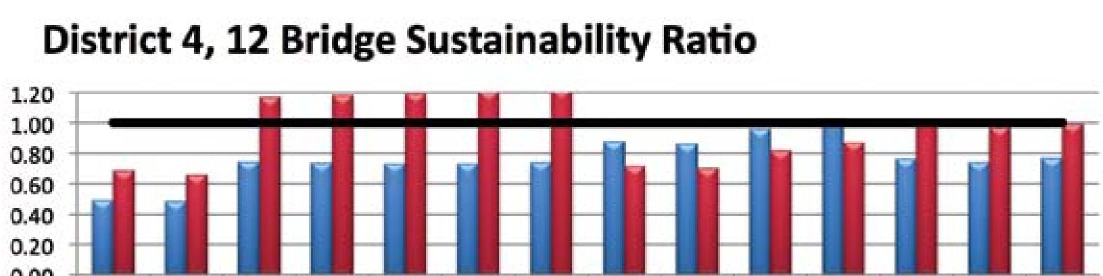
As Figure 39 illustrates, the Bridge Sustainability Ratios for the two districts moved from a low of .48 for District 4 in 1999 to 1.03 by 2008 before falling again to approximately .75. Similarly, District 12's increased from a low of .66 in 1999 to above 1.0 by 2000.

Although only two districts are illustrated here, similar calculations are possible for each district. Also, this illustration examines only one of the four Ohio deficiencies, namely Floor conditions. Similarly, Sustainability Ratios could be produced for each category of deficiency and for each district.

Such an expanded analysis would build from the "heat map" illustrations show later in Figure 43. The calculations would reflect the types of tradeoffs illustrated in Figure 40.

Figure 40 illustrates the shift in bridge budgets between 1998 and 2010 between the various districts. Starting in 1999, six district's allocations went down and six went up as a result of the trade off analyses that underlie the efforts to "normalize" conditions by pulling up the conditions in the districts with below-average bridge conditions.

Figure 41 illustrates one component of the statewide tradeoffs by illustrating the trade-off results for the ODOT District 1. It is an example of a district from which funds were reduced once it reached its condition targets. Its district bridge budget remained at between $9 million and $10 million annually from 1998 through 2004 when it reached its bridge condition goals. Bridge forecasts indicated it did not need to continue investing at that level to sustain its condition. It moved into a bridge preventive maintenance mode and the excess funds above those needed to sustain its conditions were transferred to other districts that were below their established goals. As seen in the Figure 42 data table, nearly $7 million annually was available after 2005 to transfer from District 1 to other district bridge needs. Similar trends occurred in the other six districts from which funds were reduced in that period.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
District 4 BSR	0.49	0.48	0.74	0.74	0.73	0.73	0.74	0.88	0.86	0.96	1.03	0.76	0.74	0.77
District 12 BSR	0.68	0.66	1.17	1.18	1.19	1.21	1.22	0.71	0.70	0.81	0.87	1.02	0.97	0.99
Optimum Bridge Sustainabilty Ratio	1	1	1	1	1	1	1	1	1	1	1	1	1	1

District 4 BSR — District 12 BSR — Optimum Bridge Sustainabilty Ratio

Figure 39. *Improving conditions over time.*

Figure 42 (see next page) illustrates the shifting statewide calibration of investment and results in another way. The "heat map" depicts areas of concern in "hotter" colors such as red and yellow. Shades of green illustrate the degree to which standards are being met. Each heat map includes all 12 districts and one of the four condition categories. The maps illustrate the transition from many "hot" colors in the 1990s when bridge goals were not being met to a predominance of green colors in the 2000s as goals were met. Commensurate with the changes in condition were changes in district budgets to address the deficiencies and changing priorities that the districts addressed. Ohio's overall

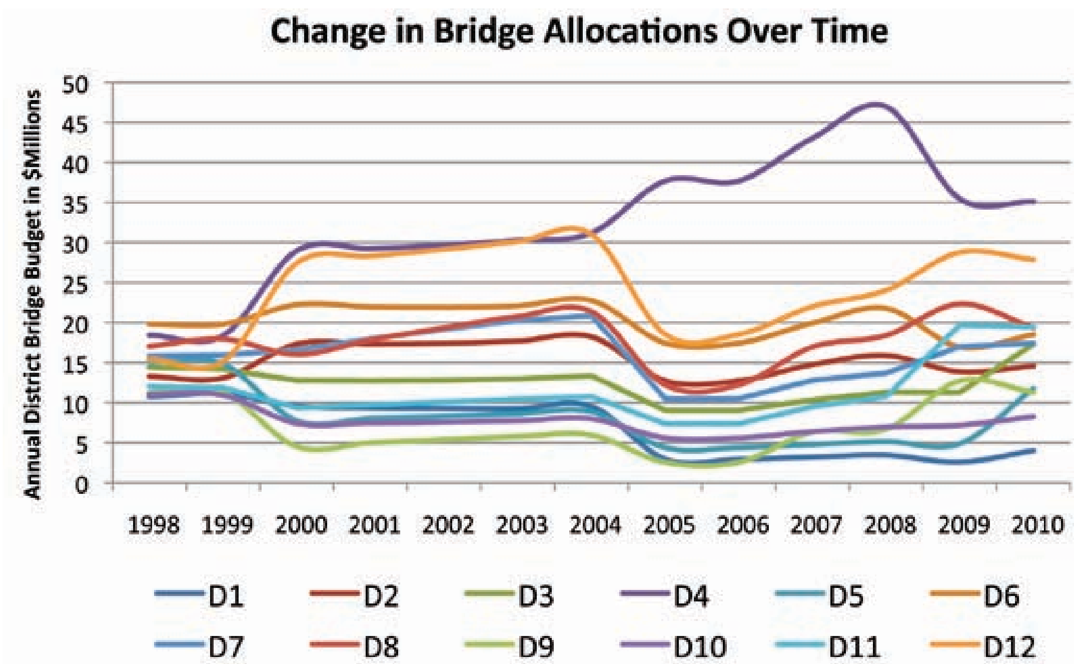
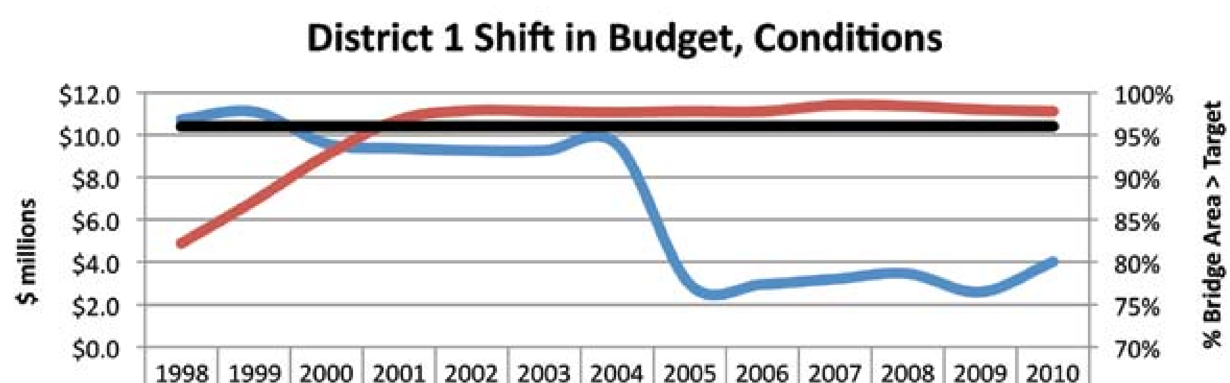


Figure 40. *Shifting bridge allocations over time.*



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
D1 Budget	$10.7	$11.1	$9.6	$9.4	$9.3	$9.3	$9.5	$2.9	$2.9	$3.2	$3.5	$2.6	$4.0
D1 Conditions	82.2%	87.2%	92.6%	96.8%	97.9%	97.8%	97.7%	97.8%	97.8%	98.5%	98.4%	98.0%	97.8%
Goal	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%

D1 Budget D1 Conditions Goal

Figure 41. *District 1 bridge funding shifts.*

Ohio DOT Floor Condition 'Heat Map"														
DISTRICT	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	98.5%	98.6%	99.0%	98.5%	98.6%	99.2%	99.4%	99.4%	99.8%	99.8%	99.8%	99.8%	99.1%	99.8%
2	98.9%	98.6%	97.5%	97.4%	97.2%	96.4%	96.4%	96.2%	96.4%	96.9%	96.9%	96.6%	96.8%	95.6%
3	96.6%	96.5%	95.7%	96.0%	96.1%	96.1%	96.2%	96.4%	96.4%	96.5%	96.3%	96.7%	97.4%	97.9%
4	86.7%	82.3%	81.0%	78.2%	79.6%	80.4%	82.0%	82.5%	89.7%	90.7%	92.3%	92.5%	93.6%	94.9%
5	95.8%	96.0%	98.1%	98.6%	98.4%	98.5%	98.8%	99.0%	98.9%	99.0%	98.5%	98.4%	98.6%	97.1%
6	99.5%	99.4%	99.3%	99.2%	99.4%	99.5%	99.6%	99.7%	99.7%	99.6%	98.9%	99.0%	98.6%	98.3%
7	97.3%	97.1%	96.6%	96.9%	97.2%	97.3%	97.3%	97.1%	97.0%	97.2%	97.3%	96.7%	97.1%	97.8%
8	98.7%	98.4%	97.3%	97.6%	97.4%	97.6%	96.6%	96.7%	97.0%	96.8%	97.4%	97.8%	98.1%	98.7%
9	98.2%	98.2%	98.2%	98.1%	98.2%	98.4%	98.4%	98.4%	97.9%	97.1%	97.0%	97.8%	97.6%	97.6%
10	99.5%	98.5%	96.3%	97.6%	97.4%	98.4%	97.9%	98.4%	97.6%	97.7%	98.3%	99.1%	99.2%	99.3%
11	97.9%	97.2%	97.0%	96.4%	96.6%	96.5%	98.2%	97.7%	97.7%	97.5%	97.3%	97.2%	97.3%	96.0%
12	85.1%	84.4%	83.9%	90.7%	92.0%	91.6%	93.4%	93.9%	94.4%	94.6%	94.9%	96.0%	96.3%	96.4%
Statewide	95.1%	94.3%	93.7%	94.2%	94.5%	94.7%	95.1%	95.3%	96.3%	96.5%	96.7%	96.9%	97.2%	97.3%

Ohio DOT Wearing Surface 'Heat Map'														
DISTRICT	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	96.0%	93.4%	94.9%	96.9%	97.5%	98.9%	99.2%	99.2%	99.5%	99.2%	98.8%	98.7%	98.5%	98.6%
2	98.2%	97.4%	97.6%	97.1%	97.6%	97.2%	97.4%	98.0%	96.7%	97.7%	97.8%	98.7%	98.8%	98.8%
3	98.4%	98.9%	98.1%	96.7%	97.0%	98.1%	97.5%	97.1%	96.7%	96.7%	96.7%	96.5%	96.1%	97.1%
4	96.4%	97.4%	98.4%	97.7%	98.3%	98.5%	99.1%	98.5%	97.8%	98.0%	97.6%	98.5%	98.5%	98.7%
5	94.2%	93.9%	96.3%	98.5%	98.8%	98.9%	98.9%	99.4%	99.3%	99.5%	99.2%	99.4%	97.9%	97.7%
6	96.2%	95.7%	90.2%	88.5%	87.6%	87.9%	89.5%	89.7%	89.9%	92.6%	93.5%	94.9%	94.8%	95.8%
7	96.1%	97.0%	97.8%	98.0%	98.4%	99.4%	99.2%	99.1%	99.5%	99.3%	99.0%	99.2%	99.4%	99.4%
8	94.4%	94.6%	97.0%	96.5%	96.8%	97.1%	97.6%	97.3%	98.0%	97.9%	98.4%	97.9%	98.4%	97.8%
9	95.3%	96.0%	96.4%	99.0%	98.5%	98.5%	98.3%	97.8%	98.0%	96.5%	97.4%	98.8%	96.4%	98.6%
10	98.8%	97.5%	96.7%	95.8%	95.5%	93.9%	92.6%	90.8%	92.6%	95.5%	95.5%	96.6%	96.7%	97.6%
11	98.0%	98.5%	98.0%	97.5%	97.2%	98.5%	98.8%	97.4%	97.7%	98.1%	98.0%	96.7%	96.9%	95.3%
12	98.8%	98.4%	98.2%	96.1%	93.9%	95.3%	96.2%	96.4%	97.3%	97.8%	98.7%	99.4%	98.5%	98.1%

Ohio DOT Floor Condition 'Heat Map"														
DISTRICT	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	98.5%	98.6%	99.0%	98.5%	98.6%	99.2%	99.4%	99.4%	99.8%	99.8%	99.8%	99.8%	99.1%	99.8%
2	98.9%	98.6%	97.5%	97.4%	97.2%	96.4%	96.4%	96.2%	96.4%	96.9%	96.9%	96.6%	96.8%	95.6%
3	96.6%	96.5%	95.7%	96.0%	96.1%	96.1%	96.2%	96.4%	96.4%	96.5%	96.3%	96.7%	97.4%	97.9%
4	86.7%	82.3%	81.0%	78.2%	79.6%	80.4%	82.0%	82.5%	89.7%	90.7%	92.3%	92.5%	93.6%	94.9%
5	95.8%	96.0%	98.1%	98.6%	98.4%	98.5%	98.8%	99.0%	98.9%	99.0%	98.5%	98.4%	98.6%	97.1%
6	99.5%	99.4%	99.3%	99.2%	99.4%	99.5%	99.6%	99.7%	99.7%	99.6%	98.9%	99.0%	98.6%	98.3%
7	97.3%	97.1%	96.6%	96.9%	97.2%	97.3%	97.3%	97.1%	97.0%	97.2%	97.3%	96.7%	97.1%	97.8%
8	98.7%	98.4%	97.3%	97.6%	97.4%	97.6%	96.6%	96.7%	97.0%	96.8%	97.4%	97.8%	98.1%	98.7%
9	98.2%	98.2%	98.2%	98.1%	98.2%	98.4%	98.4%	98.4%	97.9%	97.1%	97.0%	97.8%	97.6%	97.6%
10	99.5%	98.5%	96.3%	97.6%	97.4%	98.4%	97.9%	98.4%	97.6%	97.7%	98.3%	99.1%	99.2%	99.3%
11	97.9%	97.2%	97.0%	96.4%	96.6%	96.5%	98.2%	97.7%	97.7%	97.5%	97.3%	97.2%	97.3%	96.0%
12	85.1%	84.4%	83.9%	90.7%	92.0%	91.6%	93.4%	93.9%	94.4%	94.6%	94.9%	96.0%	96.3%	96.4%
Statewide	95.1%	94.3%	93.7%	94.2%	94.5%	94.7%	95.1%	95.3%	96.3%	96.5%	96.7%	96.9%	97.2%	97.3%

ODOT Paint Condition 'Heat Map'														
DISTRICT	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	90.2%	90.6%	90.7%	93.6%	95.9%	97.9%	98.5%	99.2%	99.2%	99.4%	99.2%	99.1%	97.9%	98.7%
2	76.8%	72.5%	76.4%	75.5%	83.8%	86.0%	86.5%	86.8%	87.2%	89.1%	89.4%	90.7%	90.2%	90.2%
3	64.0%	65.6%	74.8%	74.1%	86.9%	91.1%	91.5%	92.6%	91.2%	91.0%	91.1%	92.3%	92.1%	92.8%
4	89.4%	84.0%	81.9%	80.6%	81.9%	82.8%	85.2%	86.8%	89.2%	91.5%	93.9%	93.3%	94.3%	95.3%
5	82.9%	84.6%	85.4%	89.3%	89.8%	94.9%	95.3%	96.1%	95.8%	96.0%	95.3%	94.9%	93.1%	91.8%
6	94.2%	94.0%	90.1%	90.5%	91.1%	91.6%	93.6%	93.8%	92.2%	92.3%	91.4%	93.1%	93.0%	91.4%
7	89.3%	89.9%	91.4%	90.7%	91.0%	92.3%	93.3%	93.0%	92.0%	92.5%	91.6%	91.6%	91.5%	92.9%
8	79.8%	80.3%	81.9%	87.4%	89.4%	92.6%	93.4%	94.5%	94.1%	94.9%	95.7%	95.6%	95.6%	95.7%
9	94.3%	94.9%	94.9%	96.1%	97.5%	98.0%	97.7%	97.7%	98.8%	98.3%	98.4%	98.3%	98.5%	98.4%
10	96.7%	95.9%	96.0%	94.8%	96.4%	96.4%	94.5%	94.6%	93.3%	93.2%	93.1%	91.1%	90.8%	92.5%
11	74.9%	76.8%	80.2%	82.9%	89.3%	89.1%	92.4%	93.4%	91.8%	92.0%	92.1%	92.2%	92.9%	93.3%
12	89.2%	90.5%	93.1%	92.1%	90.9%	89.5%	87.8%	86.4%	89.8%	91.6%	92.2%	93.0%	93.4%	92.6%

Figure 42. *Heat map of bridge conditions showing shifting conditions over time.*

bridge expenditure rose steadily overall but shifted more substantially between districts over time, as seen in the case of District 4.

The Figure 42 Heat Map illustrates the steadily improving floor conditions in Districts 4 and 12 and the sustaining of overall floor conditions in the other districts and statewide. Commensurate with the subpar performance across the districts over time, were commensurate increases and decreases in bridge budgets to achieve the desired targets.

This granularity allows creation of a Bridge Sustainability Ratio for each district and for each category of bridge condition. This type of detail allows informed tradeoffs to be made.

The sustainability metrics allow "drilling down" into each asset, each asset class, or each district to calibrate needed investment. Ohio has 12 districts, 17 MPOs, 88 counties,251 cities and 1,100 townships, all who have at least partial responsibility for infrastructure. The granularity possible through the Asset Sustainability metrics allow the disaggregation of trends for localized decision making at the district, MPO, city or other level.

Figure 43 shows an estimated, recreated set of Sustainability Metrics for each category of Ohio bridge deficiency from the time period 1997 through 2016. It should be stressed that for the years before 2006, these are estimates based upon a recreation of the budget and condition assumptions for the years 1997 through 2006. In the early years of the period, the tradeoff analysis would indicate that the bridge funds should be focused primarily upon General Appraisal and Paint. As those conditions improved over time and backlogs of deficiencies were removed, the bridge program focus spread more to all four deficiency categories to ensure that all the categories reach their goals.

The years in this forecast from 2011 through 2016 indicate that the department has budgeted enough in all four bridge deficiency categories to sustain its bridge conditions, at least through the 5–year forecast. One additional element of analysis ODOT performs to further enhance its forecast is to estimate the magnitude of bridge area that is likely to fall into a deficient category within the next 5 years. It analyzes the programmed projects to determine if a sufficient amount of those "almost deficient" bridges are programmed and will be addressed in the next 5 years. The intent of that additional exercise is to further improve the chances that a large backlog of deficiencies is not pending in the years ahead.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bridge Budget	$175.00	$174.47	$174.40	$180.00	$185.00	$190.00	$196.00	$201.88	$141.00	$141.00
GA Sustainabilty Ratio	0.80	0.85	0.86	0.86	0.88	0.89	0.9	0.9	0.91	0.92
FC Sustainability Ratio	0.99	0.98	0.97	0.98	0.98	0.98	0.99	0.99	1.00	1.00
WS Sustainability Ratio	1.00	1.00	1.00	0.99	0.99	0.99	1.00	0.99	1.00	1.00
Paint Sustainabilty Ratio	0.95	0.94	0.96	0.96	0.99	1.01	1.02	1.02	1.02	1.03
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bridge Budget	$170.41	$185.00	$193.00	$204.89	$211.00	$224.00	$235.00	$247.00	$259.00	$272.00
GA Sustainabilty Ratio	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1	1.01	1.02
FC Sustainability Ratio	1.00	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.99	0.99
WS Sustainability Ratio	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Paint Sustainabilty Ratio	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04

Figure 43. *Statewide "heat map" of bridge conditions and associated sustainability ratio.*

Minnesota DOT Bridge Sustainability Analysis

Summary
The MnDOT produces long-term investment need forecasts as well as long-term budget estimates that together can produce a Bridge Sustainability Index for the department.

The MnDOT Bridge Sustainability Index and its related analyses provide important financial, policy and programming insight for State policy makers. First, the indices indicate that Minnesota will achieve and sustain its bridge condition targets through 2018. Second, the bridge investment adequacy is in contrast to the documented inadequacy of pavement investments. Third, although bridge condition targets through 2018 will be met, they will be funded through a large increase in funds to replace major structures. An equally large investment beyond 2018 appears to be needed in order to sustain the conditions of an aging inventory of State bridges, not addressed by the large-bridge program.

Background
MnDOT produces an annual Minnesota Bridges report that analyzes the conditions of the State's bridge inventory and notes important changes and trends. Minnesota State law defines a bridge as a structure over 10 feet in length, as opposed to the Federal definition for a bridge which is a structure over 20 feet. As a result, the Minnesota DOT produces extensive condition data using both the State and Federal definitions. It also analyzes and reports upon bridge conditions not only for structures under DOT control but also for ones that are owned by cities, counties, townships and railroads. The analytic data allows analysis of bridges by condition, by functional class, by ownership, by condition category and by changes over time.

MnDOT reports conditions on 3,898 structures that are over 20 feet in length, thus meeting the Federal definition, and which are on the State's "trunk" system. The Trunk Highway System consists of the interstate highways and State routes. It also reports upon another 9,813 structures over 20 feet in length that are on the local system. Finally, it reports on the 8,437 structures less than 20 feet in length on both the trunk and local systems.

Minnesota bridge conditions are above national averages. The National Bridge Inventory reports that 8 percent of the bridge area on the National Highway System is structurally deficient nationwide. In Minnesota, only 4.05 percent of the NHS bridge area is structurally deficient. Its Trunk Highway System bridges have an overall sufficiency rating of 89.9 out of a possible 100 and have an average age of 31.9 years, compared to a national average of 43 years.

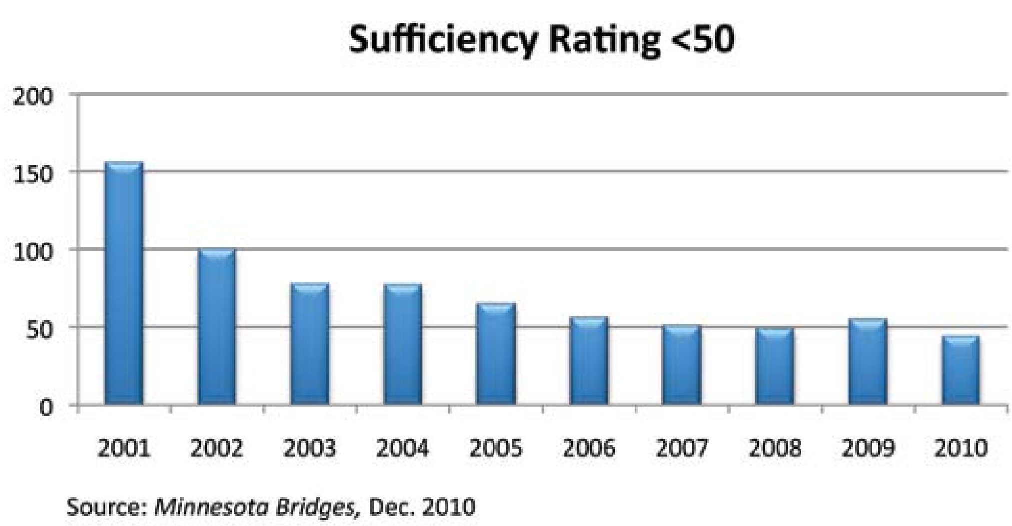


Figure 44. *Improvement in MnDOT sufficiency ratings.*

In addition, MnDOT bridge conditions have steadily improved. As seen in Figure 44, the number of Trunk Highway System bridges with a Sufficiency Rating of less than 50 steadily has declined. When measured by area, the area of bridges with Sufficiency Ratings less than 50 also has fallen from 3.6 million square feet in 2001 to 2.1 million in 2010, or a 39 percent decline.

Despite the sound current conditions, the MnDOT reporting process attempts to keep policy makers appraised of the long-term consequences of investment decisions. It notes that its percentage of bridges in the “fair” condition categories still exceeds its optimum targets. As those bridges age and sustain use, they will create future long-term liabilities for the State. The Minnesota legislature through a statute known as Chapter 152 required MnDOT to substantially increase its bridge spending following the collapse of the I-35 bridge. MnDOT is required to replace 120 bridges that are either structurally deficient or functionally obsolete. These extraordinary expenditures will improve the overall bridge inventory through 2018 but they will not address all bridges that beyond 2018 will fall into an unacceptable condition category. Structures that are not fracture-critical or structurally deficient today will not be replaced by the Chapter 152 program.

“It is important to address bridge rehabilitation and replacement needs that fall outside the Chapter 152 program,” notes MnDOT’s 2010 bridge report. “Funding of other bridge needs at the recommended investment guidance level… is highly encouraged. The deferral of investment toward those needs will compound the needs in the long-range plan years, which are more than double the amount of needs in the (2010–2018) years. Deferring bridge replacement or improvement projects may also result in more frequent reactive maintenance.”

Figure 45 illustrates the long-term trends facing Minnesota as its bridge inventory ages. More than 17 percent of its bridge inventory when measured by size already is in its fifth decade, and the inventory will steadily age. Its current bridge expenditures represent a short-term increase to address the Chapter 152 structures through 2018. Although by 2018, MnDOT will have reached its current condition targets, and complied with the Chapter 152 statute, it will face larger and more expensive costs to repair, rehabilitate and replace an even larger

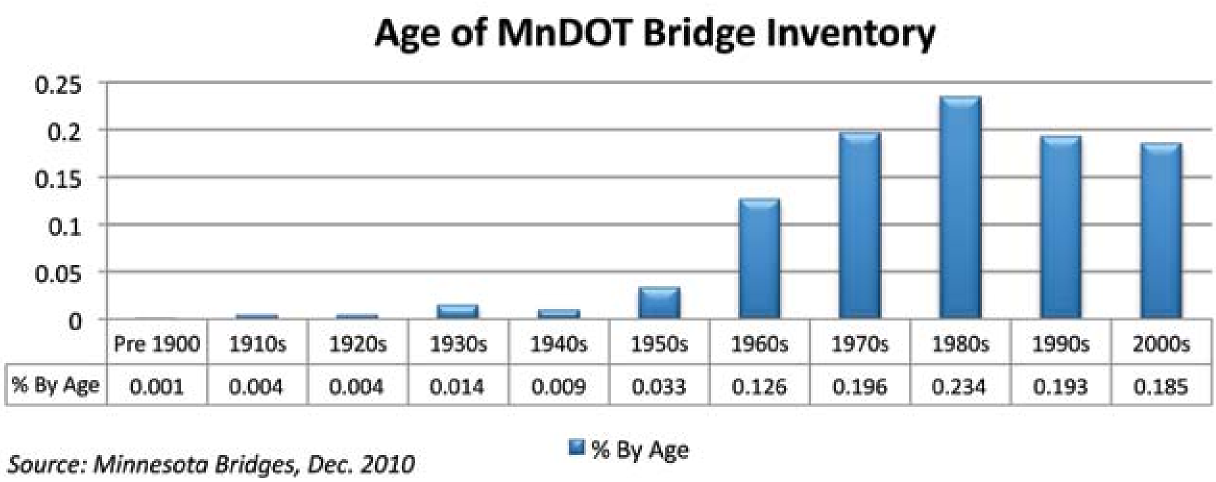


Figure 45. *Age profile of MnDOT bridges.*

pool of bridges that by 2018 will grow considerably older and will have experienced significant loadings.

Table 18 illustrates the overall good condition of the MnDOT structures today when viewed by collective averages. The average age is 32 and major categories of bridge components such as decks and superstructures have an average score in the 6s out of a maximum score of 9. As can be seen, the overall Interstate bridge inventory's sufficiency rating averages an 89 and the Trunk Highway System bridges a 90.3 out of a possible score of 100.

The MnDOT bridge report provides details that allow analysis of the bridge inventory conditions beyond the averages. In addition to the overall average conditions, it tracks the number of bridges in "fair" and "poor" condition to ensure those categories do not exceed acceptable numbers that would not be apparent if only average inventory-wide conditions were measured.

In addition to the voluminous National Bridge Inventory information the department reports, it also has set Minnesota-specific targets for its bridges. The three targets are:

- Structural Condition Rating
- Geometric Rating
- Load Carrying Capacity Rating

The Structural Condition Rating is a broad measure of the structural components of the bridge. Each bridge is categorized as Good, Satisfactory, Fair or Poor by using four National Bridge Inventory Codes and 2 NBI appraisal ratings. The four codes are Deck Condition, Superstructure Condition, Substructure Condition and Culvert Condition. The Appraisal ratings are for Structural Evaluation and Waterway Adequacy. All the condition codes and appraisal ratings are on a scale of 0–9 with 9 being excellent and 0 closed.

The Geometric Rating is a broad measure of the geometric properties of the structure. Each bridge is categorized as Good, Fair, or Poor by using the NBI appraisal categories of Deck Geometry, Under-clearance (both vertical and horizontal), Approach Roadway Alignment and Waterway Adequacy.

The Posted Bridges and Load Carrying Capacity measures the bridge's ability to carry legal and overweight loads. Each bridge is categorized as to whether it:

- Meets the modern HS25 truck weight standards
- Is not HS25 rated but still has no permit limitations or posted restrictions
- Is Permit Limited which means it is not suitable for overweight trucks operating by permit, or
- Is Posted and not suitable for full, legal loads.

Figure 46 shows the performance of bridges on Minnesota's principal arterials from 2002 through 2010. During that period, the percentage of Good bridges gradually increased while the Satisfactory bridges declined only slightly. However, there was a slight but steady increase in the Fair bridge conditions. Those bridges entering the Fair category are likely to need substantial work in the next decade and represent a long-term financial need for the department.

MnDOT reports in its 2010 bridge report and in its Highway Investment Plan Annual Update 2011–2020 that it will exceed it bridge targets by 2018. Its target is to have 84 percent of its bridge inventory on principal arterials in a Good or Satisfactory Condition. As seen in Figure 46, its 2010 conditions

Table 18. *Bridge condition statistics.*

Route System	Bridges	Culverts	Total Structures	Avg. Age	Deck	Super	Sub	Culv.	Struct. Eval	Suff Rating
Interstate	1140	70	1210	32	6.6	6.8	6.8	6.4	6.6	89
Truck	1685	744	2429	32	6.8	7.1	7	6.6	6.7	90.3

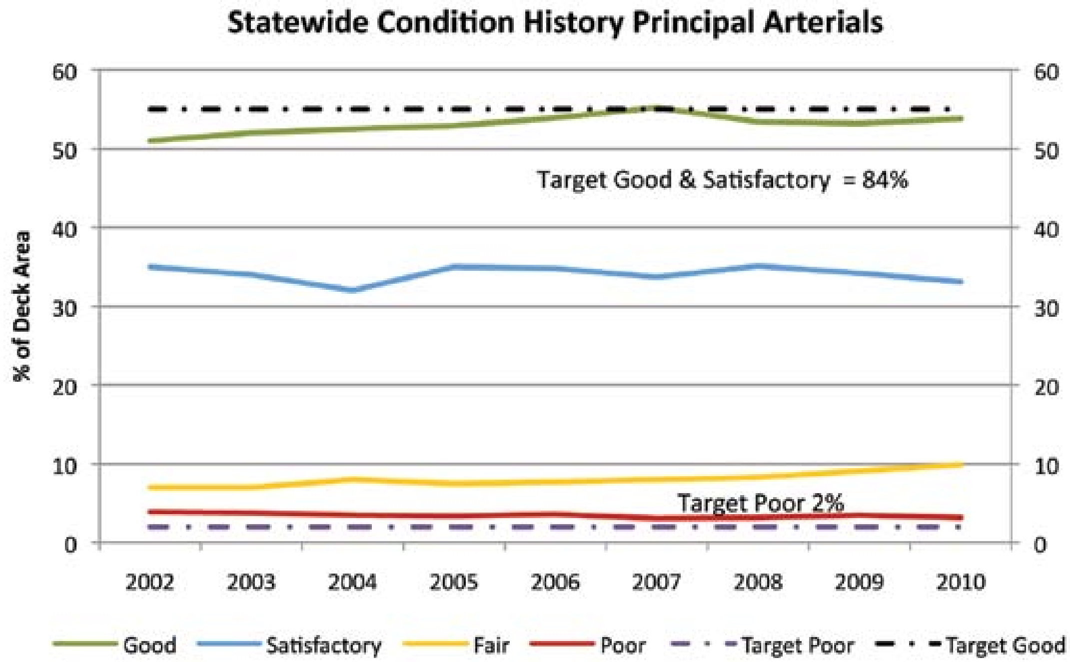


Figure 46. *Bridge conditions and targets over time.*

are that 87 percent are in Good or Satisfactory condition and it forecasts that by 2018 bridges in these categories will be up to 89 percent. The target has two components. The first, is to have 55 percent of the bridges in Good condition and at least 29 percent in Satisfactory condition. The second is to have substantially achieved the Chapter 152 goals of replacing or rehabilitating the 120 fracture-critical or structurally deficient bridges.

MnDOT's Statewide 20-year Highway Investment Plan 2009–2028 forecasts that for 2009–2019 that it needs to spend $2.420 billion to meet the Chapter 152 requirements and $725 million to meet performance targets for the remaining State bridges. Those approximate amounts are forecast to be budgeted throughout the program period as shown

Table 19. *Bridge Sustainability Ratio.*

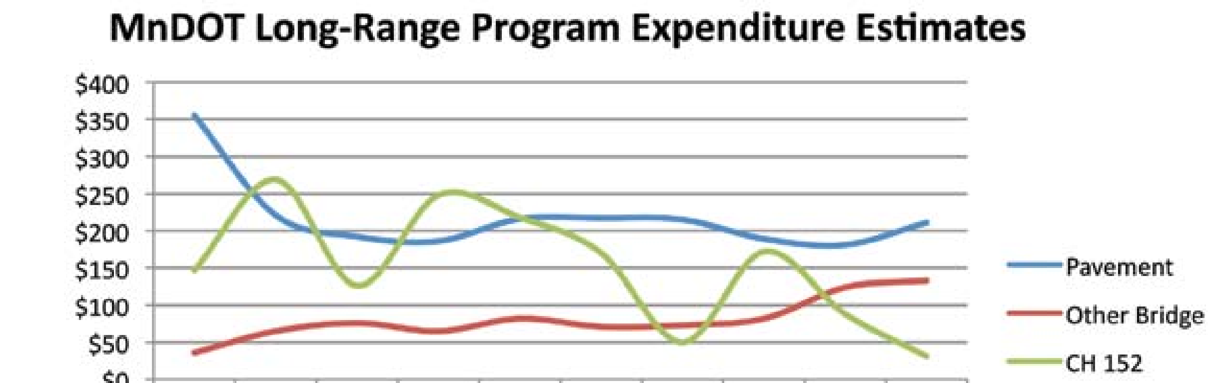
2009–2018	
Chapter 152 Need	$2,420
Chapter 152 Budget	$2,420
Chapter 152 Ratio	1.00
Other Bridge Need	$720
Other Bridge Budget	$780
Other Bridge Ratio	1.08

in Table 19. As seen in Table 19, the sustainability ratios for the Minnesota bridges therefore are positive, indicating adequate investment over that period.

These sufficient levels of investment through 2018 are in contrast to those reported in the pavement section, Chapter 4, which indicated pavement investment budgets were only 72 percent of the level needed to sustain condition targets through 2018.

Although MnDOT will have achieved its bridge condition targets through 2020, its reporting provides insight into even longer-term implications. As seen in Figure 47, the Chapter 152 bridge expenditures significantly exceed those of the regular bridge program. The Chapter 152 bond funds fluctuate through the years based upon when the large structures are ready for bid. The annual Chapter 152 expenditures decline through the period and end by approximately 2020. Although the Chapter 152 expenditures will address 120 large structures, those are a small percentage of the State's 3,898 structures over 20 feet in length. The 2010 bridge report includes the statistics from Figure 46 that show that while the Good and Poor Categories have improved, the "Fair" condition bridges have increased between 2006 and 2010.

As the bridge inventory ages, the "Fair" bridges will experience additional loadings, require



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pavement	$355	$221	$192	$186	$216	$217	$215	$189	$181	$211
Other Bridge	$36	$65	$76	$65	$82	$71	$73	$82	$124	$133
CH 152	$147	$269	$126	$248	$218	$170	$50	$172	$88	$31

Figure 47. *MnDOT long-term investment trends.*

additional repair, and some percentage of the Satisfactory bridges likewise will slide into the Fair or even Poor categories. These represent a long-term obligation for the department. The Statewide 20-Year Highway Investment Plan from 2009 indicates that predicted financial need from 2019–2028 to sustain the bridge condition targets jumps to $2.004 billion in the non-Chapter 152 structures. That $2.004 billion need number for the decade from 2019–2028 decade is 176 percent higher than the amount budgeted in the 2009–2018 decade for the non-Chapter 152 bridges. In effect, an amount approximate to the Chapter 152 program will be needed in the following decade just to sustain MnDOT's structures at targeted levels in the decade 2019–2028.

The amount to be available in the years 2019–2028 is highly uncertain. That period represents a fairly distant future in terms of legislative and appropriation cycles. However, MnDOT has made an estimate of available revenue predicated on an assumption of no new sources of revenue or rate increases. It estimates that approximately $6.530 billion will be available from 2019–2028.

MnDOT's recommended investment strategy with that revenue is to invest 84 percent of it into infrastructure preservation, 8 percent into safety improvements, 5 percent into mobility enhancements, 4 percent into regional and community improvement projects and 2 percent into related costs such as right of way and engineering. MnDOT articulated a clear hierarchy of priorities, with the following ranking:

1. Bridge preservation
2. Traveler safety
3. Pavement preservation
4. Other infrastructure preservation
5. Capacity improvements for traveler safety
6. Interregional Corridor mobility
7. Greater Minnesota Metropolitan and Regional Mobility
8. Regional and Community Improvement Priorities.

This recommended investment strategy is subject to change from several events including a planned update to the Statewide 20-Year Highway Investment Plan.

These priorities led to MnDOT's recommendation to substantially increase investment in the non-Chapter 152 bridges in the 2019–2028 period to $1.820 billion, compared to approximately $780 million in the preceding decade. With that substantially increased investment in its bridge inventory, MnDOT predicts that it can create a sustainable bridge inventory through 2029. However, the same report also notes the decline in the State's pavement conditions on the non-principal arterials. The department reports that a lack of sufficient revenue leads to the consequence of underfunding pavements on non-principal arterials in order to meet the bridge and safety targets, and to meet pavement targets on the principal arterials.

Conclusion

The long-term perspective provided by the MnDOT analysis allows policy makers to understand the approximate magnitude of long-term bridge needs. As the agency's bridges age, as construction prices rise and as loadings increase on the bridge inventory, the level of expenditure that today is seen as extraordinary to respond to the Chapter 152 requirements could become the norm just to sustain conditions.

Table 19 shows that through the 2018 period, the department forecasted a Bridge Sustainability Index near the optimum of 1.0 for both the Chapter 152 bridges and the regular bridge inventory. MnDOT proposes a continued increased investment level in bridges beyond 2018 as it fulfills the Chapter 152 requirements and shifts the investment focus to the State's remaining bridge inventory. If MnDOT's investment strategy for 2019–2028 comes to pass, the analysis indicates that MnDOT can provide the State a sustainable bridge inventory that continues to meet condition targets.

The type of analysis that MnDOT produces also allows creation of a Bridge Sustainability Ratio, providing another example of how a U.S. transportation agency could replicate the type of ratios that are used in policy analysis in Great Britain, Australia and elsewhere.

North Carolina DOT Bridge Sustainability Analysis

Summary

The North Carolina DOT (NCDOT) applies its bridge management system's forecasting capability to produce long-term scenarios of bridge needs that allow it to produce analyses very similar to a Bridge Sustainability Ratio. The department has reported that if current funding levels remain the same, bridge condition improvements of the past decade are likely to reverse. Additional long-term investments of up to 45 percent higher than past investment levels will be needed to sustain current bridge network conditions. The NCDOT sustainability ratio-like analyses depict both the magnitude and the cost of long-term investments to sustain bridge conditions.

Bridge Condition Data

The NCDOT notes that a comprehensive, sustainable infrastructure management approach provides the highest levels of conditions for the lowest cost over the lifecycle of its bridges. It uses a mix of treatments of maintenance, preservation, rehabilitation, and replacement. Its budgeting process primarily relies on State funds for programming its maintenance and preservation programs and Federal Highway Bridge Program (HBP) funds for rehabilitation and replacement. The Department has recently executed an agreement with FHWA for an Interstate Preservation Program for pavements, bridges and other roadway assets using Federal Interstate Maintenance funds to proactively improve performance on that network.

The NCDOT structures data come from the federally required biennial bridge inspections, as well as from the inspection of pipes and culverts. These address not only the bridges over 20 feet in length that qualify as a federally recognized bridge but they also apply to pipes and culverts.

NCDOT divides its State funded bridge structure and maintenance work into two categories of programs, Recurring and Performance-Based Programs. Recurring programs include drawbridge maintenance, small bridge replacements, large culvert installation and maintenance and scour/slope replacements.

Its Performance Based activities include the maintenance and repair of many bridge elements. A detailed analysis of those items is conducted through the Bridge Condition Survey. The inspections assess the condition of the State system highway bridges for five major elements, railings, decks, expansion joints, superstructure, and substructure. As each bridge is inspected every two years, survey teams assess the condition of the elements for each bridge. Element conditions are determined for each bridge and summarized into a statewide Bridge Condition Rating. In addition, the survey teams determine the quantity and type of repair needed. These inspections and assessments then are used to calculate the statewide bridge maintenance needs. The process also provides the level of service for decks, superstructures, substructure, rails and expansion joints and produces an estimated annual cost to maintain these elements at the targeted levels.

The Recurring and Performance-Based Programs both complement the NCDOT's policy of sustaining acceptable condition targets for the lowest-lifecycle costs. The Recurring funds "come off the top" either because their activities are legally mandated or because they are known to contribute to sound long-term maintenance of structures. These would include bridge inspection, drawbridge maintenance, culvert maintenance, debris removal around piers, slip protection, approach slab maintenance and other activities as shown in Table 20. Table 20 also illustrates the significant degree of granularity that the NCDOT analysis provides for agency executives, external policy makers or the public. It breaks down Recurring expenditures in 11 categories, all which relate to key infrastructure activities necessary to sustain its bridges.

Table 21 includes the maintenance programs for Performance Based categories. Again, significant granularity is provided which allows for insightful analysis and tradeoff decisions.

The detail provided by the bridge investment analysis shown in Tables 20 and 21 illustrate that a Bridge Sustainability Ratio could be produced for each category of expenditure. What is not known at this time, is what the budget amounts will be for each category through 2017–2018. Those amounts have not been appropriated. However, the type of mature bridge management analysis produced by the NCDOT illustrates that a Bridge Sustainability Ratio could be forecast not only for the total bridge inventory but also for various categories as shown in Tables 20 and 21.

Two other categories of expenditures are components of the department's lifecycle approach to its bridge management. The first category is an active Bridge Preservation Program that consists of minor, low-cost treatments performed on bridges that are in relatively good condition. These activities include

Table 20. *Recurring bridge needs and activities*

	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Recurring Bridge Activities							
Culverts	$ 2.35	$ 2.45	$ 2.55	$ 2.66	$ 2.77	$ 2.89	$ 3.01
Clearing & Slp Prot.	$ 1.72	$ 1.79	$ 1.87	$ 1.95	$ 2.03	$ 2.11	$ 2.20
Drawbridges	$ 2.79	$ 2.91	$ 3.03	$ 3.16	$ 3.29	$ 3.43	$ 3.57
Bridge Repl.	$ 6.29	$ 6.55	$ 6.83	$ 7.12	$ 7.42	$ 7.73	$ 8.05
Bridge Inspect.	$ 2.37	$ 2.47	$ 2.57	$ 2.68	$ 2.79	$ 2.91	$ 3.03
Approach Slabs/Surfacing	$ 0.24	$ 0.25	$ 0.26	$ 0.27	$ 0.28	$ 0.29	$ 0.31
Drift and Debris Removal	$ 1.81	$ 1.89	$ 1.97	$ 2.05	$ 2.13	$ 2.22	$ 2.32
Small Pipe Maint & Repl't	$ 6.15	$ 6.41	$ 6.68	$ 6.96	$ 7.25	$ 7.55	$ 7.87
Walls and Tunnels	$ 0.22	$ 0.23	$ 0.24	$ 0.25	$ 0.26	$ 0.27	$ 0.28
Walkways	$ 0.13	$ 0.14	$ 0.14	$ 0.15	$ 0.15	$ 0.16	$ 0.17
Bridge Fender Systems	$ 3.00	$ 1.00	$ 1.00	$ 1.00	$ 1.00	$ 1.00	$ 1.00
Total	$ 27.07	$ 26.08	$ 27.13	$ 28.23	$ 29.38	$ 30.57	$ 31.81
(in $millions)							

Table 21. *Bridge maintenance program categories.*

Performance Based Activities	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Railings	$ 1.44	$ 1.50	$ 1.56	$ 1.63	$ 1.70	$ 1.77	$ 1.84
Bridge Decks	$ 13.04	$ 13.59	$ 14.16	$ 14.75	$ 15.37	$ 16.02	$ 16.69
Expansion Joints	$ 4.85	$ 5.05	$ 5.27	$ 5.49	$ 5.72	$ 5.96	$ 6.21
Superstructures	$ 11.62	$ 12.11	$ 12.62	$ 13.15	$ 13.70	$ 14.27	$ 14.87
Substructure	$ 13.63	$ 14.20	$ 14.80	$ 15.42	$ 16.07	$ 16.74	$ 17.45
Total	$ 44.58	$ 46.45	$ 48.40	$ 50.44	$ 52.55	$ 54.76	$ 57.06

painting structural steel, cleaning bearings, repairing and replacing expansion joints, applying materials to slow corrosion, waterproofing or resurfacing decks. The other category is Bridge Rehabilitation, which includes treatments to restore bridge components to "like new" conditions. Rehabilitation is cost effective when some portions of a bridge are in good to fair condition but other components are in poor condition. The poor condition components can be rehabilitated without having to replace the entire bridge.

If a bridge is deteriorated to the point that it is not economical to bring it to acceptable condition through preservation, maintenance or rehabilitation, it becomes a candidate for replacement. Those structures are matriculated to the replacement program and are funded through the capital programs, largely funded through the Statewide Transportation Improvement Program (STIP.)

Performance Reporting and Tradeoffs

Table 22 illustrates two significant aspects of the NCDOT process for managing its bridges. First, the table illustrates the tradeoffs inherent in the setting of condition targets. The targets for the high-volume Interstate Highway System are consistently higher than for the Primary or the Secondary system. Also, the targets are more frequently obtained on the Interstate Highway System than on other two networks. The DOT in recent years has increased its investment emphasis on the Interstate Highway System as part of its performance-based approach to asset management. Since the State is responsible for most of the public road system, local divisions and staff work closely with local communities and residents on the local routes. That has created a long-standing focus on local routes. In recent years as the department shifted to a more data-driven, asset management-based approach, it has set higher standards and directed more resources to the higher-volume Interstate Highway System. This was driven in part by the adoption of a Statewide, Long-Range Multimodal Transportation Plan in 2004 that broke the highway network into three distinct tiers, Statewide (Interstate/NHS), Regional (NC/Lower importance U.S.) and Sub-regional (secondary and municipal routes) based on their function and level of importance.

In 2008 the NCDOT developed and implemented a Bridge Health Index (BHI) as a means of providing a composite evaluation of its bridge conditions and to use in conjunction with the companion performance metrics and targets. Originally, the BHI was based on a composite score of 18 or higher using the 0-9 NBI ratings for Deck, Superstructure and Substructure with the caveat that none of these components could be rated below a "6". Bridge Performance metrics were developed using a similar approach to that employed for pavements based on percent "Good." Performance Targets were established for each of the previously discussed network tiers. The NCDOT has since modified its BHI to incorporate a factor for weight restrictions in addition to the component conditions such that the average of all four factors must be a "6" or higher for a bridge to be considered in

Table 22. *NC bridge conditions, targets.*

Bridge Conditions			Interstate		Primary		Secondary		Statewide
			2010	State Average	2010	State Average	2010	State Average	Average
	Element	Performance Measures	Target	Score	Target	Score	Target	Score	
Bridge Deck	Concrete	% of decks rated greater than or equal to 6	85	85	80	79	75	84	82
	Timber		85	NA	80	86	75	88	88
	Steel Planks		85	NA	80	71	75	84	84
	Open Grid Steel		85	NA	80	50	75	33	47
Superstructure	Concrete	% of superstructure rated greater than or equal to 6	90	81	85	60	80	65	62
	Steel		90	89	85	82	80	81	82
	P/S Concrete		90	96	85	95	80	94	94
	Timber		90	NA	85	43	80	69	68
Substructure	Timber	% of substructure rated greater than or equal to 6	90	NA	85	40	80	42	42
	Concrete Pile		90	80	85	75	80	81	77
	Steel Pile		90	91	85	84	80	81	82
	Concrete Piers		90	91	85	81	80	82	82
Other	NBIS Culverts	Conditon Rating >=6	85	86	85	86	85	89	87
	Non-NBIS Culverts	Condition Rating = Good	80	84	80	74	80	56	71
	Overhead Sign Structures	Condition Rating = Good	95	95	95	93	95	88	92

"good" condition. The performance targets are outlined above in Table 22 for the network. It should also be noted that the NCDOT is now in the process of converting NBI condition values to the new AASHTO Condition States.

The mature management systems that the NCDOT use allow it to conduct optimized trade-off analyses between its pavement, bridge and maintenance programs. It has run the scenarios as part of its planning and programming process. To date, however, the computerized optimization analyses between asset classes have not been a determinant in final decisions of how much to invest in the different asset classes. It remains one of several factors including department policy, input from the Board of Transportation, engineering judgment and other factors.

The data-driven NCDOT bridge process also allows for significant transparency in reporting to the Board of Transportation, the Legislature and to the public. As seen in Table 22, six of 10 of the bridge condition targets on the Interstate Highway System were met, with four other categories falling just short of target for a "yellow" rating. On the Primary system, only two of 12 categories met their target, another six were close for a "yellow" score and four were significantly below target for a "red" score. On the Secondary system, nine categories met their target, one was just below for a "yellow" rating and five were significantly below for a "red" rating.

These types of more detailed measures are reported in the annual Maintenance Condition and Assessment (MCAP) Report presented to the Legislature. The same type of data is compiled into a simpler dashboard set of performance metrics tracked continuously on the DOT website. For the website metrics, the Department consolidates the bridge, pavement and maintenance condition data into an Infrastructure Health Index that is comprised of a health index for each category.

The Bridge Health Index has reported the following scores over time as shown in Figure 48.

Although the department's network-wide Bridge Health conditions have improved as shown in Figure 48, it warns that if bridge investment levels do not increase, that these positive trends will reverse. The Department reports that higher material prices, increases in traffic, and expansion of the highway network necessitate higher investments to sustain these conditions over the next decade. Its management systems forecast that if expenditure levels remain at current levels, the percentage of bridges in "good" condition is projected to decline from 62 percent in 2011 to approximately 54 percent by 2017 as seen in Figure 49.

Using its management system forecasting capability, the department estimates that between 2012 and 2021, bridge investments will need to total

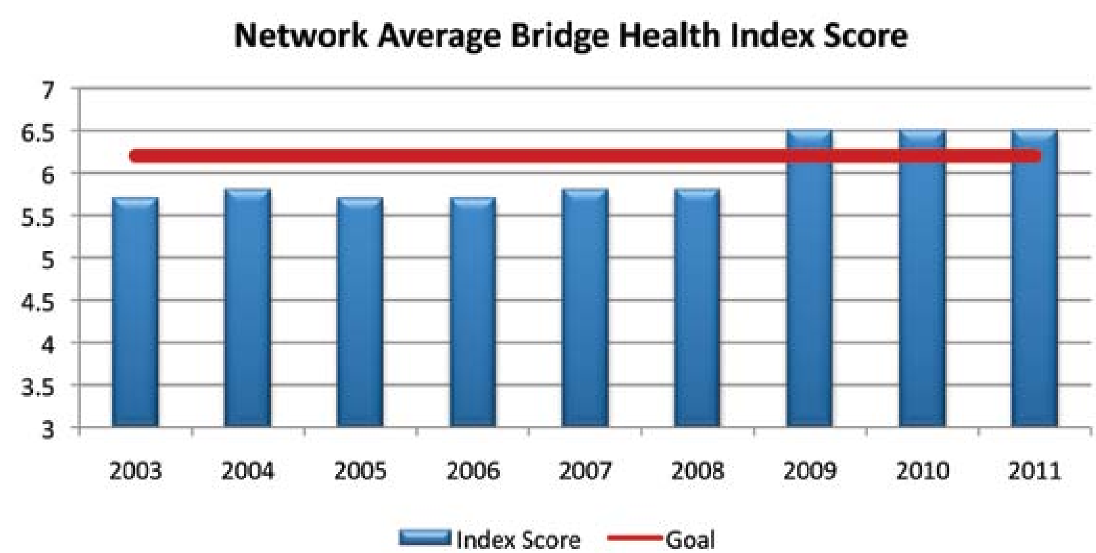


Figure 48. *North Carolina network-wide bridge health conditions.*

$3.918 billion, compared to the $2.169 billion spent in the preceding 10 years. These numbers allow the depiction of Bridge Sustainability Ratios to be illustrated based upon different spending scenarios. If the expenditures are flat, the Bridge Sustainability Ratio for the next decade would be only .55. That is based on:

$$\frac{\text{Budget} \quad \$2.169 \text{ billion}}{\text{Need} \quad \$3.918 \text{ billion}}$$

However, the department has drafted tentative long-term bridge allocations shown in Table 23.

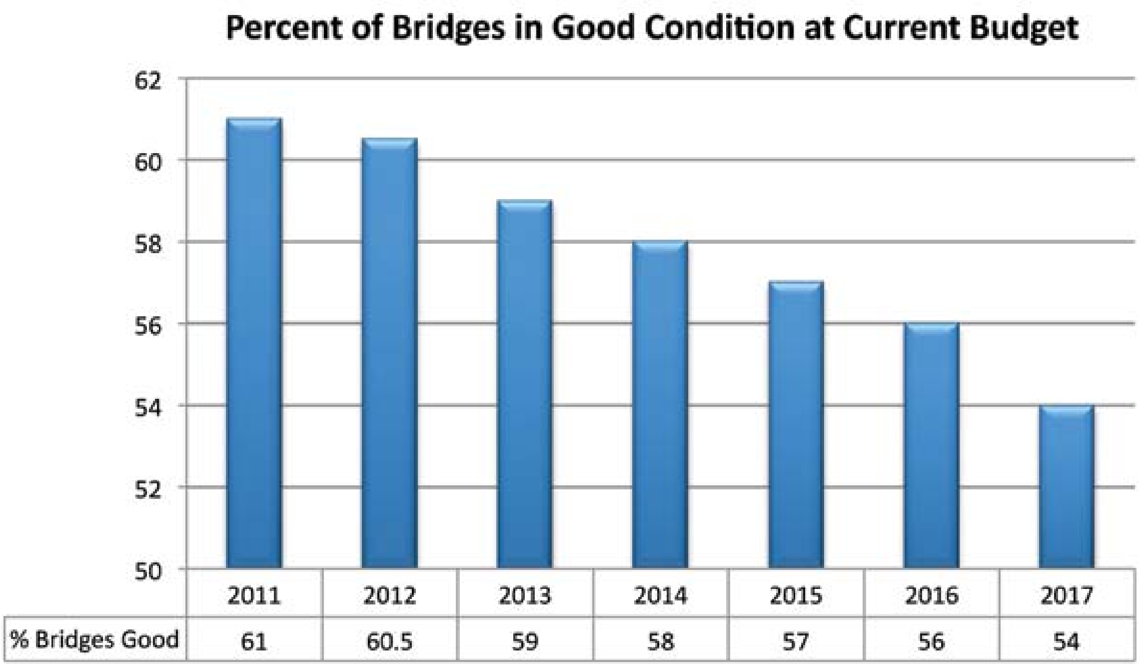


Figure 49. *Forecasted decline in bridge health at current expenditure levels.*

Table 23. *Recommended expenditure levels.*

(Federal HBP and IM for All Systems – Interstate, Primary, Secondary)

Activity	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021*
Preservation	$45	$45	$45	$50	$50	$50	$50	$50	$50	$50
Rehabilitation	$0	$0	$0	$25	$25	$25	$25	$25	$25	$25
Replacement	$191	$155	$95	$154	$179	$204	$229	$254	$254	$254
Total HBP & IM Sys. Pres	$236	$200	$140	$229	$254	$279	$304	$329	$329	$329
NCDOT Projected State Funding for Bridge Program (Primary & Secondary)										
Preservation	$15	$15	$15	$15	$15	$15	$15	$15	$15	$15
Maintenance and Repair incl. Elec. Sys.	$59	$59	$59	$59	$59	$59	$59	$59	$59	$59
Rehab-Non Recurring	$225	$225	$0	$0	$0	$0	$0	$0	$0	$0
Replacement of small bridges	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12
Total State Maint & Pres	$311	$321	$86	$86	$86	$86	$86	$86	$86	$86
Total Bridge Program – All Systems and Funding Sources										
Maintenance	$59	$59	$59	$59	$59	$59	$59	$59	$59	$59
Preservation	$60	$60	$60	$65	$65	$65	$65	$65	$65	$65
Rehabilitation	$225	$235	$0	$25	$25	$25	$25	$25	$25	$25
Replacement	$203	$167	$107	$166	$191	$216	$241	$266	$266	$266
Total All Funds	$547	$521	$226	$315	$340	$365	$390	$415	$415	$415

*2021 estimated same as 2020

The higher expenditures assumed for Table 23 would generate just over $3.9 billion over the next decade, which would increase the Bridge Sustainability Ratio to just over 1.0 at 1.007. The two scenarios illustrate for policy makers the magnitude of the investment necessary to sustain the department's bridge inventory at its current levels.

Conclusion

As stated in the opening chapter, the intent of this report is to illustrate the proof of concept of the sustainability ratios and to illustrate how they can provide policy makers with enhanced understanding of the needed levels of investment required to sustain the highway system into the future. Although, the North Carolina budget categories and asset class definitions vary considerably from the other case study States in this report, its extensive asset management systems and sophisticated budgeting process provide the data to produce bridge sustainability ratios that are germane to North Carolina policy makers. Current investment levels are near the optimum 1.0 for the Bridge Sustainability Ratio but that will need to increase in the next decade by more than 40 percent above the average invested in each year of the past decade. Such analysis allows policy makers to understand not only how the physical conditions of the highway system are likely to change, but also how to calibrate the levels of investment necessary to sustain conditions indefinitely.

CHAPTER 6

Example of U.S. Maintenance Sustainability Ratio

This case study illustrates how a Maintenance Sustainability Ratio can be computed using data from a State's maintenance management system. The case study illustrates that the MSR can be an important component of decision-making. However, the case study also illustrates the caution that must be used in interpreting the MSR values. The accuracy of the MSR is no better than the accuracy of the inventory condition data that underlies it. Because maintenance management systems must address a large number of assets, over a large area which can change significantly year to year, a good deal of engineering judgment is necessary for interpreting short-term, or geographically specific Maintenance Sustainability Ratios.

Maintenance Asset Sustainability—The Utah DOT Case Study

Since 1997, Utah DOT (UDOT) has been using the Maintenance Management Quality Assurance program to evaluate the effectiveness of its maintenance program. The program provided various reports to support data-driven decisions. The agency used historical budget information adjusted for inflation in making maintenance allocations for future years. The program was modified in 2003 to provide some enhanced decision-support features that included:

- Guidance for feature condition thresholds that would trigger maintenance actions
- Information to help make data and needs-driven projections in allocating funds for maintenance activities
- Tools to help communicate maintenance needs and decisions to key stakeholders
- Help in measuring the Level of Maintenance (LOM) of the highway system.

The enhanced program is called Maintenance Management Quality Assurance Plus (MMQA+). The MMQA+ helps the agency address its strategic goal of ***"Taking Care of What We Have"*** at the statewide, regional and station level.

The MMQA+ program is expected to provide valuable information to:

- Optimize the allocation of budget to maintenance activities at the statewide, regional and station level
- It also provides information to help the agency decide where it needs to allocate more funds and where it could reduce funds without major negative impact
- With improved inspection and reporting and 4 to 5 years of historic information, the agency expects to establish targets for future levels of maintenance based on budget availability and current system conditions.

The information from MMQA+ with few modifications will provide all the information that the agency needs to compute the Maintenance Sustainability Ratio component of the Asset Sustainability Index.

The agency acknowledges that with between 200 to 400 agency personnel at the station level inspecting 19 major categories of maintenance activities there are bound to be differences in the identification, scoring and reporting of deficiencies.

The data that are input at the station level are summarized and uploaded to the regional level. These data are further summarized at the regional level and uploaded to provide statewide reports on the LOM of each activity.

Sustainability Ratios for Select Maintenance Activities

Across the nation, agencies are changing the focus from expansion and building of new infrastructure to preserving and maintaining the existing infrastructure. Agencies have also developed systems and processes to help them monitor and report on the condition and performance of the system. This focus on preserving and maintaining its infrastructure resulted in UDOT receiving the highest rating from Governing magazine of any State for taking care of its infrastructure in 2005.

The agency has successfully used the information and performance of its maintenance activities to inform the legislature about how it uses the maintenance funds to take care of the transportation infrastructure under its charge. The agency focuses on preserving and maintaining its infrastructure and has the legislature echoing its philosophy that ***"Good Roads Cost Less."***

To ensure consistency in the collection and reporting of the condition of the infrastructure, as well as to ensure a common understanding of all maintenance deficiencies, the agency has focused attention and resources on training. The agency has one person in the central office focused on training the field personnel on how to conduct the inspections. The agency also conducts audits of maintenance activities for quality-assurance purposes. Additionally, UDOT also has an MMQA+ manual that provides detailed instructions about desired conditions, reporting guidelines and what constitutes a feature being "deficient." The reporting guidelines also provide information about the measurement frequency, measurement area and how to record the count of deficiencies. They also provide photographs for each maintenance activity to help the inspector differentiate between deficient and non-deficient features.

Target Setting

To work towards a common goal for performance of maintenance activities, statewide targets are set for each maintenance activity. Targets are expressed as letter grades A, B, C, D or F. The targets at the statewide level are generally set to be A through C. These statewide targets also apply to the regions and stations. Each route is divided into segments and stations are responsible for multiple segments of a route.

The expectation is for each station to achieve, but not exceed, its performance target. Station personnel inspect assigned routes and record both the total number of features that need to be maintained, as well as the number of deficient features. The data from the inspection are entered into the MMQA+ software. The system then computes the LOM and assigns a score from A through F. Reports generated by the software allow the agency personnel at different levels of the organization to review the performance achieved for each maintenance activity. Reports also provide valuable information to manage available budget and other resources. It also allows the stations to prioritize and focus on specific activities based on agency priorities, current conditions, available budget and achievement targets.

The agency tracks close to twenty maintenance features. For this study and proof of concept of the Maintenance Sustainability Ratio, the following five maintenance features/activities are being studied:

1. Shoulder Work
2. Pavement Striping
3. Pavement Markings
4. Signs and Posts
5. Guardrail Maintenance

Background on Measuring Level of Maintenance

The station personnel can view in the MMQA+ system the performance target that has been set for each of the maintenance activities for the station. Based on current conditions of maintenance features, available budget and target performance, the station supervisor prioritizes and schedules work activities.

The frequency of measurement varies with the activity. For example, Signs and Posts are inspected at least bimonthly. The remaining four activities are inspected semi-annually. The inspection involves identifying the percent of deficient features to total features. For each measurement, the MMQA+ manual provides detailed information about the following:

- Desired condition
- Deficient condition

- Frequency of measurement to be taken
- Measurement area
- How to record total count of feature
- Count of deficient item
- Comments for clarification.

Based on the number of deficient items identified and entered into the system, the software computes the LOM and assigns a letter grade based on the number of deficiencies recorded in the MMQA+ system. Table 24 below shows the grades for the five maintenance features discussed in this study.

Figure 50 below shows the target, performance achieved and amount expended for the five maintenance features from 2009 through 2011. It also shows the budgeted amount and the target of performance established for 2012.

Table 24. *Maintenance grades.*

Percent Deficient	Grade	Percent Deficient	Grade
0.00 – 3.43	A+	26.82 – 30.00	C-
3.44 – 6.83	A	30.01 – 33.40	D+
6.84 – 10.02	A-	33.41 – 36.79	D
10.03 – 13.42	B+	36.80 – 39.99	D-
13.43 – 16.82	B	40.00 – 43.39	F+
16.83 – 20.01	B-	43.40 – 46.78	F
20.02 – 23.41	C+	46.79 – 100.00	F-
23.42 – 26.81	C		

Figure 50 shows that amount budgeted for 2012 for each of the maintenance activities is higher than the amount spent in the previous three years with the exception of guardrail. The next few charts will discuss each maintenance activity in more detail.

Shoulder Work: Analysis of the data

Table 25 (see next page) shows the target, score and expenditure for 2009 through 2011 for Shoulder Work. It also shows the target and the amount budgeted for Shoulder Work for 2012.

Figure 51 (see next page) shows in red the target performance established for Shoulder Work. Deficiencies are not to exceed 20.01 but were much lower as seen in the blue line. The overall score for shoulder work would indicate that the agency scored much better than the target that was established in 2009, 2010 and 2011.

The Maintenance Sustainability Ratios are intended for long-term budgeting and programming decisions. When computing the Maintenance Sustainability Ratio (MSR) the focus is to achieve the performance target that has been established over the long term. For any give year, or for any given asset such as shoulders, the Sustainability Ratio may be less useful because conditions such as shoulder conditions can change rapidly.

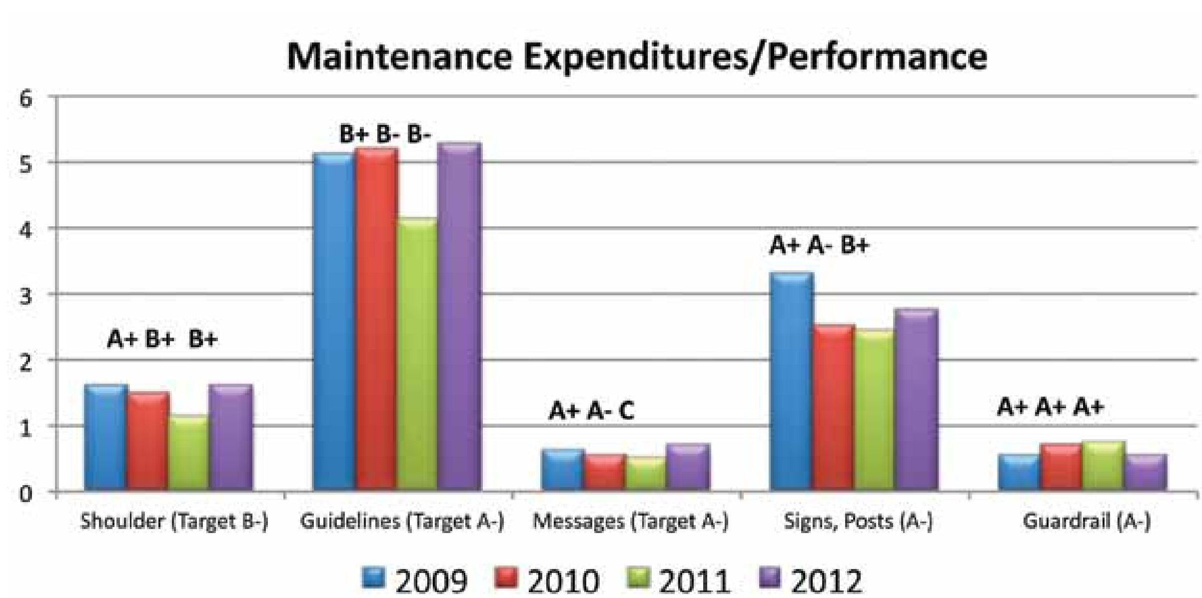


Figure 50. *Targets, Performance, Expenditure and Budgeted Amounts.*

Figure 51 shows that the agency achieved a score that is better than (below) the established performance target of allowable deficiencies. It appears that the agency could have spent less in 2009, 2010 and 2011 to achieve the established target of a "B-" instead of exceeding the target and achieving an "A+." However, because shoulders can change rapidly, an agency may want to have higher-than-target conditions to allow for "robustness" in case of heavy rains or other factors that could rapidly erode shoulder conditions. Figure 51 and Table 25 show that the agency anticipates that an increase in funds will be needed to address shoulder work in 2012. After deficiencies increased in 2010 and 2011, the agency will increase expenditure to 2009 levels to address the growth in shoulder deficiencies.

Pavement Striping: Analysis of the Data

Table 26 shows the target, score and expenditure for 2009 through 2011 for Pavement Striping. It also shows the amount budgeted and the target set for 2012.

Table 25. *Shoulder Work – Target, Score, Dollars Spent or Budgeted.*

	2009	2010	2011	2012
Shoulder Work – Letter Target	B-	B-	B-	B-
Shoulder Work – Letter Score	A+	B+	B+	
Shoulder Work – Target	20.01	20.01	20.01	20.01
Shoulder Work – Score	0.3475	10.665	13.1625	
Shoulder Work – $ Spent	$1,582,355.75	$1,467,542.00	$1,116,167.65	$1,590,000.00

Figure 51. *Shoulder Work-Score, Target and Expenditure.*

Figure 52 shows in red the target established for Pavement Striping for years 2009 through 2012. It shows in blue the scores achieved in Pavement Striping for years 2009 through 2011. The amount budgeted for 2012 and the expenditures incurred for years 2009, 2010 and 2011 are shown as columns in green.

$$\frac{\text{Maintenance Capital Budget}}{\text{Maintenance Capital Needs}} = \text{Maintenance Sustainability Ratio}$$

The optimum MSR is a 1.0. Table 26 shows that the agency was close to achieving an optimum MSR in 2009 for pavement striping. It also shows that for 2010 and 2011, the percentage of deficiencies was much higher than that permitted by the target and accordingly the agency's score in both years was below target. This would also indicate that the amount budgeted for 2010 and 2011 in the area of Pavement Striping was not sufficient to meet the needs. The amount budgeted for 2012 is more $1 million above the amount spent for 2011 and it is assumed that this amount would be sufficient to achieve the target performance for 2012.

Table 26. *Striping scores, conditions, expenditures.*

	2009	2010	2011	2012
Pavement Striping–Letter Target	A-	A-	A-	A-
Pavement Striping–Letter Score	B+	B-	B-	
Pavement Striping–Target	10.02	10.02	10.02	10.02
Pavement Striping–Score	10.99	19.755	19.16	
Pavement Striping–$ Spent	$5,088,059.05	$ 5,167,910.00	$ 4,116,958.00	$5,268,754.00

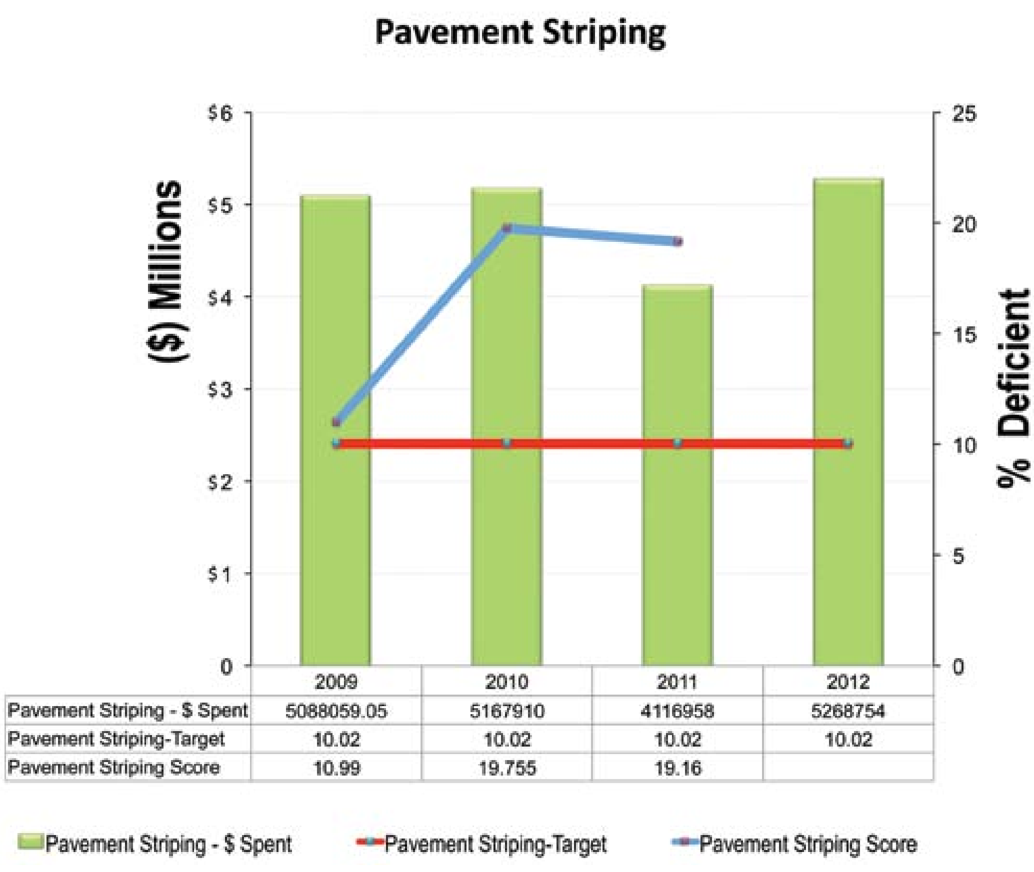


Figure 52. *Pavement striping condition, expenditures.*

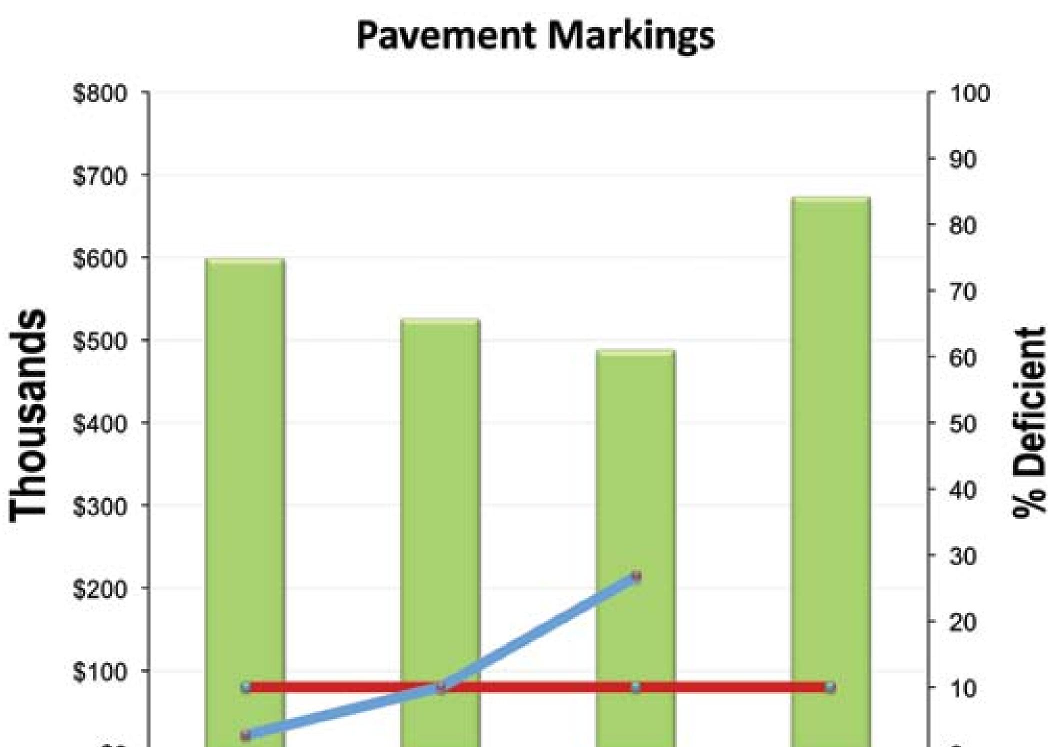
Pavement Markings: Analysis of the Data

Table 27 shows the target, score and dollars spent for 2009, 2010 and 2011 for Pavement Markings. It also shows the amount budgeted and performance target that has been established for 2012 for Pavement Markings.

Figure 53 shows in red the target established for Pavement Markings for years 2009 through 2012. It shows in blue the scores achieved in Pavement Markings for years 2009 through 2011. The amount budgeted for 2012 and the expenditures incurred for years 2009, 2010 and 2011 are shown as columns in green.

Table 27. *Pavement markings scores, expenditures.*

	2009	2010	2011	2012
Pavement Markings – Letter Target	A-	A-	A-	A-
Pavement Marking – Letter Score	A+	A-	C	
Pavement Markings – Target	10.02	10.02	10.02	10.02
Pavement Marking – Score	2.75	10.02	26.7	
Pavement Messages – $ Spent	$597,368.86	$524,566.00	$486,754.00	$672,195.00



	2009	2010	2011	2012
Pavement Messages $ Spent	597368.86	524566	486754	672195
Pavement Markings -Target	10.02	10.02	10.02	10.02
Pavement Marking -Score	2.75	10.02	26.7	

Figure 53. *Pavement marking targets, expenditures.*

Table 27 shows that in 2009 the score achieved for Pavement Markings is an "A+" which is higher than the target score of "A-" and in 2010 it achieved a score of "A-" which met target. However, in 2011 the score was "C."

In 2009, the agency exceeded the established target with the allocated funds. This indicates the MSR for 2009 is greater than 1.0. In 2010, the department exactly met target with a slightly smaller expenditure. In 2011, it reduced the expenditure again and the number of deficiencies rose to more than twice the number set in the target. In 2012, the agency increased its budget for pavement markings. This example illustrates how an agency adjusts budgets in an attempt to achieve the optimum MSR of 1.0.

Signs and Posts: Analysis of the Data

Table 28 shows the target, score and expenditure for 2009 through 2011 for Signs and Posts and the amount budgeted and target established for 2012 for Signs and Posts.

Figure 54 shows in red the target established for the maintenance category Signs and Posts for years 2009 through 2012. The figure also shows in blue the scores achieved in Signs and Posts for years 2009 through 2011. The amount budgeted for 2012 and the expenditures incurred for years 2009, 2010 and 2011 are shown as columns in green.

Table 28 shows that in 2009 the score of an "A+" achieved for Signs and Posts is above the target required of an "A-". In 2010 the target score of an "A-" was achieved. In 2011 the statewide score for Signs and Posts was a "B+" which is below the target established of an "A-."

Since the score achieved for 2009 is above the expected target, the MSR for 2009 would be greater than 1.0 while the MSR for 2010 would be a 1.0 indicating that the amount spent met the condition needs to address Signs and Posts. In 2011 with an expenditure of approximately $ 2.4 million, the target score of "A-" was not achieved. If the MSR was computed for 2011 it would be a number slightly less than the optimum MSR of 1.0. However, the agency scores are very close to target. The agency increased the signs and posts budget slightly in 2012. In 2010, 2011 and 2012 the agency has fairly closely calibrated expenditures to remain near its target.

Guardrail: Analysis of the Data

Table 29 shows the target, score and expenditure for 2009 through 2011 for Guardrail. It also shows the amount budgeted for 2012 to be approximately

Table 28. *Sign post scores, expenditures.*

	2009	2010	2011	2012
Signs and Post – Letter Target	A-	A-	A-	A-
Signs and Posts – Letter Score	A+	A-	B+	
Signs and Posts – Target	10.02	10.02	10.02	10.02
Signs and Posts – Score	4.92	9.77	11.54	
Signs and Posts – $ Spent	$3,279,576.71	$2,515,046.00	$2,406,382.00	$2,719,846.00

Table 29. *Guardrail condition, expenditures.*

	2009	2010	2011	2012
Guardrail – Letter Score	A+	A+	A+	
Guardrail – Letter Target	A-	A-	A-	A-
Guardrail – Target	10.02	10.02	10.02	10.02
Guardrail – Score	0.0225	2.42	2.5475	
Guardrail – $ Spent	$527,770.00	$687,092.00	$709,390.00	$526,200.00

	2009	2010	2011	2012
Signs and Posts-$ Spent	3279576.71	2515046	2406382	2719846
Signs and Posts -Target	10.02	10.02	10.02	10.02
Signs and Posts-Score	4.92	9.77	11.54	

Signs and Posts-$ Spent   Signs and Posts -Target   Signs and Posts-Score

Figure 54. *Sign, post conditions expenditures.*

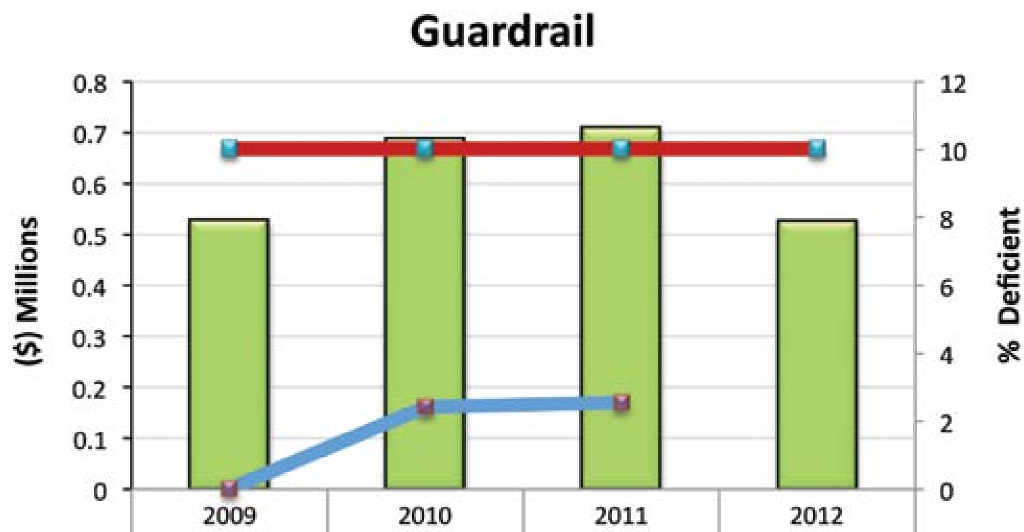
$526,200 dollars and the performance target established for 2012 is an "A-".

Figure 55 shows in red the performance target established for Guardrail for 2009 through 2012 and the expenditures in green through 2011 and the budget for 2012. Table 29 and Figure 55 show that in 2009 the agency spent $1,582,356 on guardrail and achieved an "A+", which exceeded its "A-" target. The next year, 2010, it decreased expenditure slightly and it again surpassed its condition target by scoring an "A+." The following year, it decreased expenditures further and again achieved an "A+." In 2012, it increased the budget slightly, closer to the levels of 2009.

Conclusions

This case study illustrates that a Maintenance Sustainability Ratio can be calculated with the data from a robust maintenance management system. However, the Utah example illustrates that some engineering judgment is needed to calibrate expenditure levels to reach targets unless the agency is completely satisfied with the accuracy of its inventory data, its condition assessments and its inspection process. The agency has devoted considerable effort to the continuous improvement of its inventories, its inspection consistency and to its budget estimates. All of these concerns directly affect the accuracy and usefulness of the Maintenance Sustainability Ratio. The accuracy of the MSR is dependent upon the accuracy and the reliability of the underlying data.

The Utah case study illustrates that using the MSR for specific assets in specific years must be done with judgment. This is because maintenance inventories are very large and are often incomplete. The conditions of assets such as shoulders or pavement



	2009	2010	2011	2012
Guardrail -$ Spent	527770	687092	709390	526200
Guardrail -Target	10.02	10.02	10.02	10.02
Guardrail-Score	0.0225	2.42	2.5475	

Figure 55. *Guardrail performance, expenditure.*

markings can change rapidly. Also, a large number of personnel are involved in assessing conditions in the field, and this can lead to variability. All of these factors require that maintenance management systems and the production of an MSR will always remain a work in progress tempered by engineering judgment.

The example demonstrates that when the MSR is "rolled up" and looked at over a number of years it can be useful for long-term budgeting, programming and resource allocation. However, care must be used when assessing the accuracy of an MSR for a specific maintenance asset class that is subject to rapid changes in conditions.

The usefulness of the MSR will be more apparent in future years as UDOT continues its improvement of the maintenance management system. More complete inventory and condition data in the next few years will provide a much more robust Maintenance Sustainability Ratio for the State.

Considerations and Lessons Learned

Inspection and reporting of the condition of features in the maintenance category involves reporting the condition and deficiency of a large range of transportation assets along the State maintained roadway. Much of the inspection is subjective and time consuming. The performance scores for each of the maintenance features also depend on the time of year when the inspection is being conducted and whether the inspection is done on a select sample. In the case of Pavement Striping, the condition of the sample that is selected for inspection will further influence the scores. It is also important to note that the score will depend on the total inventory of the asset that is recorded in the system.

It can take several years for the full 100 percent asset inventory to get updated in a system. As the inventory updated in the system gets close to 100 percent, the reports generated will become increasingly useful to decision makers in projecting budgets for future years. The expectation is that after a few years of implementation of the MMQA+ the entire maintenance inventory will get captured in the system. This will result in a more holistic reporting of condition of the overall system and its performance. As the historic budget and inventory information gets closer to reflecting the overall system conditions, the agency will find computation of MSR more useful for allocating future budgets as well as in moving budgets across categories.

Historically according to the DOT *"budgeting for the maintenance program was an incremental process based on historical expenditures, plus a small increase for inflation."* With the implementation of the MMQA+ the agency has now moved to a zero based budget. Each year's budget for the next year is projected based on system conditions, available budget and target of performance that is expected for the projected year. The goal of the agency is similar ***to the intent of the Maintenance Sustainability Ratio*** to *"manage resources at all levels such that they are diverted towards activities that are falling short of their targets and away from activities whose targets are being exceeded."*

The intent is that station supervisors can review the current conditions, established targets and available budgets in the MMQA+ and request money be moved across categories within their stations to effectively address focus areas/ priorities to best meet established targets. The UDOT regional directors have the flexibility to move regionally allocated funds across various categories within stations and across stations within their region.

The agency uses the reports from MMQA+ to communicate with the legislature, the transportation commission and other key stakeholders. It also uses the information at a state-wide level to develop budgets and establish targets for future years. A Quality Assurance (QA) process has been instituted for the MMQA+ program where each station has a QA check done once every year. Each station gets audited on either the monthly and bimonthly measures or on the full gamut of measures. The program is coordinated and conducted by the Central Maintenance area. With the training and the improvements taking place in the DOT in data collection and inspection, the agency will be able to realistically compute the MSR and also project the future budget needed to meet performance targets for future years.

The agency is continuing to look at all parameters that may need to be modified in order to get better projections for targeted level-of-maintenance and the cost associated with achieving the revised targets.

Detailed Observations

The following factors will have a bearing on the accuracy of the MSR and should be considered as examples of the types of issues that need to be addressed if developing an MSR.

Shoulder Work: Studying the data on Shoulder Work for 2009 through 2011 the MSR was above a 1.0. If one examined only the MSR data, it would indicate that the agency is spending more than the required budget to attain the goals established for each of the years. This would imply that the agency should reduce the budget for Shoulder Work. The agency reduced expenditures in 2011 and the number of deficiencies increased. For 2012, the agency increased shoulder work expenditures closer to the 2009 levels. This increase in budget reflects that the agency has shoulder work needs that are not reflected in the MMQA grade.

Pavement Striping: The analysis indicates that for 2009 the budget for Pavement Striping was about optimum as the agency met its target. However, in the next year with a similar budget the number of deficiencies doubled. The agency reduced expenditures slightly and yet scores slightly improved. The following year, 2012, the agencies increased the budget to a record amount.

While analyzing the data it is important to know that Pavement Striping is a *"subjective measure of the observed condition of longitudinal markings on UDOT routes."* The reporting is done semiannually. The measurement is taken on 1/10th mile sections of the highway on ten representative sections within the station boundary selected by the station supervisor. These factors were considered in setting the 2012 striping budget.

Pavement Markings: The analysis indicates an MSR greater than 1.0 in 2009, an MSR at 1.0 in 2010 and less than 1.0 in 2011. An MSR greater than 1.0 in 2009 would imply the 2010 budget could be reduced, which occurred. However, the number of deficiencies increased. When the budget was further reduced in 2011, the deficiencies increased further, resulting in a substantial budget increased in 2012 in an attempt to reduce deficiencies and achieve the target.

The agency takes into consideration, that similar to inspecting and scoring of Pavement Striping, Pavement Marking is also *"a subjective measure of the observed condition of pavement messages on agency highways including word messages, crosswalks, stop bars, turn arrows, painted/taped medians, islands etc."* The inspecting for reporting is done semiannually and the measurement area includes all messages on the agency maintained roadways. The manual provides detailed descriptions and examples of all markings that need to be counted. For example, the total messages on every route are taken and every marking lacking reflectivity, worn, not visible, faded or chipped is to be counted as a deficiency. For counting purposes, each letter, each arrowhead on a multi-headed arrow and each 2' x 10' bar on a high visibility crosswalk is recorded. The total inventory, the time of inspection and the number inspected will influence the scoring received.

Signs and Posts: The data and analysis shows that in year 2009 the MSR is greater than 1.0 indicating that the agency has put more money than necessary into this maintenance category to achieve the target score. In 2009, the agency exceeded the required target. In 2010 the agency budget was decreased. For 2010 the Signs and Posts category has the optimum MSR of 1.0 and the agency achieved its target score of an "A-". The 2010 scenario shows that the agency decreased its budget to the amount necessary to achieve the established target performance. In 2011, the score achieved was a "B+" which is very close to the target established of an "A-" In 2012 the agency has marginally increased the budget to achieve the target score of "A-" for 2012.

Signs and Posts are inspected and reported bimonthly. It is a *"measure of the observed condition of sign installations along the agency's highways."* The measurement area includes all agency maintained roadways/roadsides. The total number of sign installations for each route or route segment is to be recorded and the number of sign installations that do not meet the standard is to be counted and recorded. A detailed description of deficiency is included in the manual. For example, signs are classified as deficient for insufficient retro-reflectivity, worn or missing characters in message, incorrect sign height, incorrect lateral clearance, missing hardware, and broken posts.

Guardrail: The analysis of data in this category indicates that in all three years (2009, 2010 and 2011) the agency has scored an "A+" which is higher than the target score of "A-." The data indicates that the agency has an MSR slightly greater than 1.0. It would indicate that the agency is assigning above- optimum amounts in this maintenance category, however, guardrail condition is important to achieving the safety goal of the agency. Guardrail inspection involves *"measuring the condition of guardrail, concrete barriers and cable barriers on State routes."* Deficient condition includes panels being damaged, leaning, or bent, broken posts, offset blocks, missing panel and connection hardware, or sagging guardrail sections or cable runs. The reporting for this category is semiannual. The measurement area includes all agency maintained roadways/roadsides. The measure of total guardrail is the entire length in feet of barrier, guardrail and cable barrier along the route. UDOT has a strong emphasis on all categories of safety which is reflected in its budgeting.

Lessons Learned

The scores, targets and budgeted amounts from the five areas of UDOT's maintenance activities as well as the QA process instituted by the agency provide some valuable insight into the usefulness of the Maintenance Sustainability Ratio in establishing needs and budgets for future years. They also provide good examples of how MSR can be used to communicate with key stakeholders the agency's logical approach to computing budget needs and optimizing funds to meet infrastructure maintenance needs. Besides computing the MSR, steps that might be helpful include the following:

1. **Develop detailed documentation guidelines for inspection:** Many agency personnel will be involved in data collection. It is important to have detailed guidelines to ensure consistency in inspection and data collection.

2. **Document how to use the guidelines:** Provide detailed documentation on the desired condition, the deficient condition, how the deficiency should be interpreted and provide examples and photographs of the desired and deficient condition. Include information about the measurement frequency, the measurement area and how to record the total count of each deficiency.

3. **Ensure that inspection is done consistently across the State.** Important budget as well as prioritization and resource allocation decisions are based on the reports generated from the inspection conducted and the data entered into various systems. It is important to ensure that the inspection is done consistently and data entered is consistent and accurate across the State.

4. **Provide ongoing training on inspection and data collection:** Process and personnel changes occur in every agency and providing training through a centralized area helps increase agency capacity to perform as well as instill consistency in inspection and data collection throughout the State.

5. **Have a forum to discuss the results:** It can takes several years of working with the processes, inputting data and discussing the performance report before agency personnel can fully appreciate and understand the implications of entering or not entering data into the system. Having a forum to discuss and analyze the performance across stations/counties and districts/regions statewide allows different regions/station/counties to see the results of the inspection data being entered and also compare and contrast results across the State. It also encourages discussion by stations that show below target performance with those that have achieved or exceeded targets. This will trigger discussion about inspection processes, desired conditions, deficient conditions, data collection and input differences. This should help over time with not only improvement in scores but also with consistency in inspection and recording of deficiencies, all of which contribute to variance in final scores.

6. **Discuss the relationship of budgets to performance targets:** In the Utah example, the stations and regions that appeared to meet or exceed the established targets were to receive budgets similar to the previous year adjusted for inflation. Further drilling into the details helped the agency identify that inconsistency in the way inspections were being done, along with differences in the interpretation of what should be looked at to identify and measure a deficiency, all contributed to inaccuracies and disparities in performance scores.

7. **Have random review of deficiencies by externals to identify areas of improvement:** Have a central team different from the team that does routine inspections do follow-up quality assurance inspections to provide feedback and suggestions on areas of improvement to station, district/county personnel who are doing the inspection and data collection.

8. **Give three to four years of cycle time for processes to improve and data to be accurate:** Because there is no automated way of inspecting and grading all the maintenance features and because people have to inspect the maintenance features and grade the features, the system is dependent on the expertise and experience of the personnel and the overall maturity of the process. Generally it takes anywhere from two to four years for all aspects of the inspection and data collection to mature and be integrated as routine work. Though the agency receives valuable information from the inspection data from the very first year, the confidence in the data is generally considered high after the first few years.

9. **Start computing the MSR each year but use the ratio with caution until the data and process matures:** Computing the MSR provides valuable insight into the budget needs as well as the scores achieved for the amount budgeted. In the Utah case based on the scores achieved and the dollars spent the figures show that there are some inconsistencies/gaps. This is useful information that helps the agency to drill into various aspects of the inspection process and the data entered to figure out what additional improvements needs to be made.

10. **Use the MSR in communicating with internal users as well as external stakeholders:** The more an agency uses MSR in its discussion internally the more the internal users understand the value of the ratios and the need to improve inspection and condition data. This will lead to improvement in the overall consistency, accuracy and reliability of the data. Using MSR in communicating with external stakeholders makes it easier to communicate the need for upkeep of various maintenance assets as well the need for budget to maintain these assets. The concepts discussed in the MSR are about expected performance (target performance) and the budget needed to maintain the targeted performance.

Ohio Maintenance Sustainability Ratio

The definition of what constitutes "maintenance" has varied between the individual States examined in this report. As noted in Chapter 1, this report does not try to impose one definition of maintenance. Instead, the case studies illustrate how three different States calculate maintenance needs and conditions, and therefore could calculate a

Maintenance Sustainability Ratio to meet their own needs.

Ohio's maintenance management system has evolved, but for the sake of this report, sample data from 2002 through 2007 are used. This particular data was readily available and did not require the Ohio Department of Transportation to produce ad hoc reports to supply new data to test the concept of a maintenance sustainability ratio. It should be noted the Ohio DOT has changed its maintenance measurements from those illustrated in this report but the data used in this example illustrate that maintenance sustainability ratios can be produced using data commonly available from States' maintenance management systems.

Ohio Maintenance Categories

For nearly a decade, the department emphasized eight major categories of roadway maintenance attributes for the maintenance performance system. They were:

1. shoulder drop offs
2. drainage ditch obstruction
3. vegetation obstruction of signs or guardrail
4. sign deterioration
5. pavement deficiency
6. pavement markings
7. guardrail
8. litter.

In this report, the litter data are not examined. The department emphasized other important maintenance functions as well such as snow and ice control, crack sealing, traffic signal maintenance and other common activities. However, the seven features noted in this section represent common activities for which performance targets were set and expenditures could be compared to the achieved targets.

Ohio's maintenance management process differed from some other States' in that it did not use a commercial maintenance management system. It used a team of internal raters who drove 100 percent of the highway system each year and used geographical positioning system (GPS) and linear referencing technology to document each observed maintenance deficiency in the eight roadway categories listed above. Through the use of touch screen technology, (Figure 56, below) the raters would log from a menu the deficiencies observed at a given location. Those deficiencies were recorded and they were logged into geo-spatially referenced mapping and tabulated numerically. With this process, the number of deficiencies observed each year could be tabulated and the deficiencies' locations could be mapped. The mapping and tabulations were used by both central office and district personnel to set maintenance priorities, track accomplishments and record progress. As seen in Figure 57 below, the mapping provided locations for maintenance personnel where the observed deficiencies were found.

Also a seen in Figure 57 (see next page), these deficiencies are for one quadrant of one county. Each quarter, one fourth of the State system was mapped, providing 100 percent coverage over the course of each year.

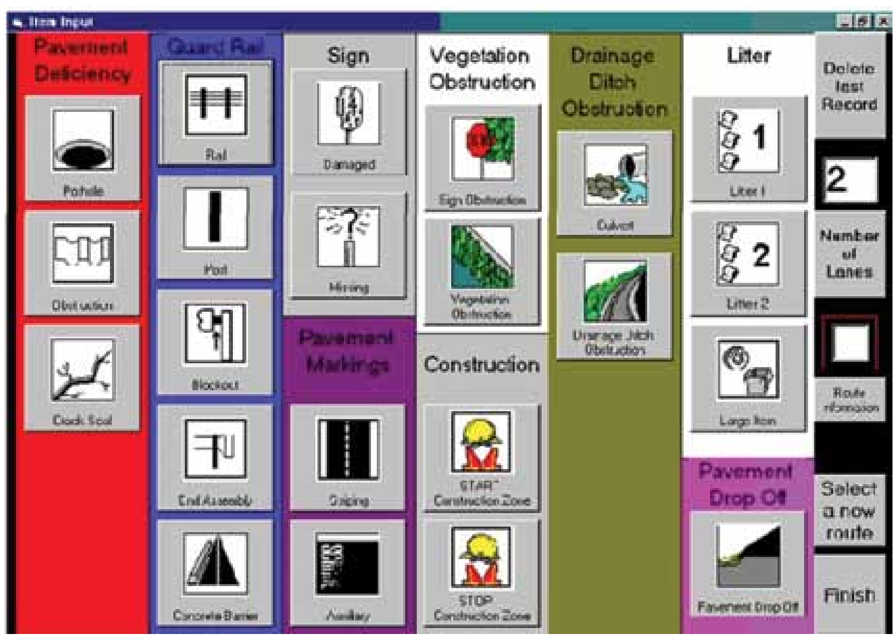


Figure 56. *Touch screen menu of deficiencies.*

Target Setting and Resource Allocation

Targets were set for each maintenance condition. Each individual category had its own number of deficiencies per mile that were considered acceptable and its own definition of what constituted a deficiency. For instance for shoulder drop offs, a difference of four or more inches between the pavement surface and shoulder for more than 20 feet was deemed a deficiency. A guardrail deficiency could be a rotted block or post, a damaged rail or a rail that was too high or low. Different scales of acceptable number of deficiencies were set. Generally, a lower number of deficiencies were tolerated for the Priority System and a higher number for the General System.

Ohio had, in effect, two scales. One very generalized scale was on a 1-6 gradient for the ODOT's Organizational Performance Index (OPI.) The OPIs provided a common series of metrics to compare more than 60 performance categories Department-wide. Within each maintenance category, thresholds were set for gradients of scores that could be translated into the more simplistic scale of 6 being the highest and 1 the lowest.

Each district controlled a budget that allowed it to prioritize its employee labor hours, its equipment usage and maintenance contract dollars. The maintenance dollars could be used to buy materials, let small maintenance contracts, rent equipment or take other actions to augment internal resources to achieve the maintenance targets. The districts and each individual county produced an annual Work Plan that allocated the labor, equipment, materials and contracts to specific maintenance target categories. The Work Plan format was intended to match resources with results and allow the process to determine over time how many resources were needed to sustain the targeted maintenance conditions. When the process first began in the early 2000s, it was not known how many resources would be needed to sustain the targeted maintenance conditions across the State. Gradually, over the years, the needed level of effort was more closely estimated but it was still affected by unpredictable events such as flooding, harsh winters or other events.

As seen in Figures 58 and 59 the total number of deficiencies would be tracked in the Work Plan, as well as the level of effort devoted to addressing the deficiencies in terms of labor hours and contract work. In Figure 58 and 59, TMS refers to the Transportation Management System that tracked the hours of maintenance personnel. The internal labor hours in TMS and the external contract dollars tracked through the Construction Management System (CMS) provided the total level of effort devoted to addressing the maintenance deficiencies.

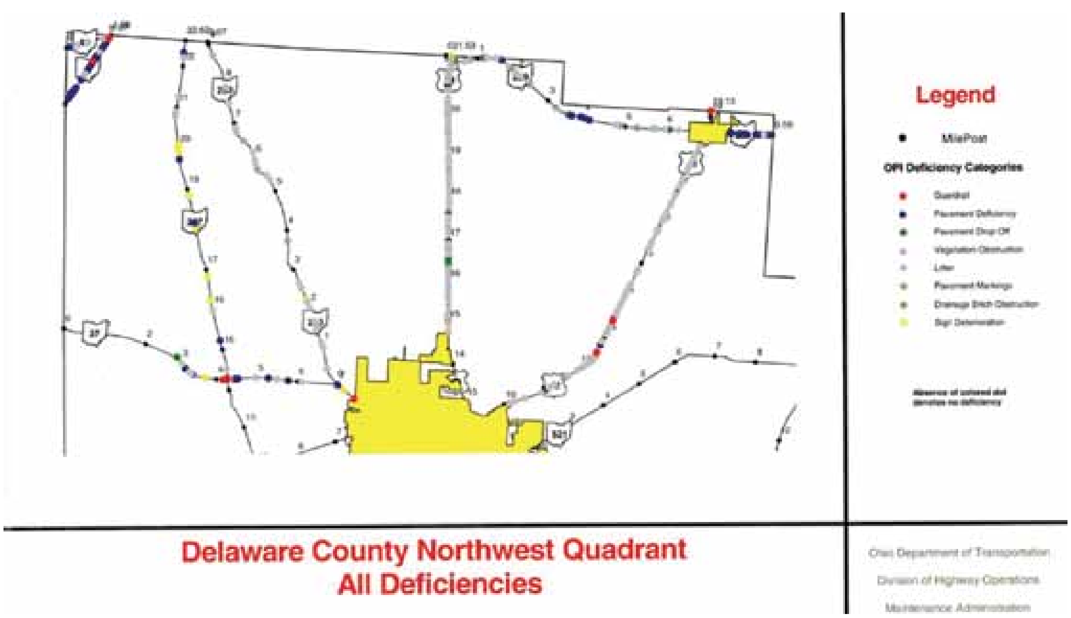


Figure 57. *Map of maintenance deficiencies in one county quadrant.*

Selected Maintenance Expenditure Analysis

This section examines a few selected examples of Ohio's maintenance expenditure and compares them to the needed level of investment to illustrate that sustainability ratios could be calculated with the Ohio system, and the data it produces.

In Table 30 (see next page), the expenditures and conditions related to guardrail are shown for the period 2002 through 2007. As can be seen, the guardrail conditions met or exceeded the established target for each year of the period. The actual amount "needed" for guardrail that would serve as the denominator is imprecise in these examples because the precise definition of "need" was not determined at the time by ODOT. However, it is apparent from the expenditures and the resulting conditions those expenditures achieved that ODOT was meeting and sustaining its guardrail conditions. In fact, ODOT consistently exceeded its guardrail minimum goal by investing to achieve its highest score, a 6, on its Organizational Performance Index.

Available Resources Category	Number of Employees	Total Hours	Compensation Time		Training	
			04/01/02	03/31/03	04/01/02	03/31/03
Highway Workers	133	276,640	6,969		11702	
Project Inspector	29	60,320	1,709		1290	
All Other Workers	76	59,350	405		955	
Totals	238	396,310	9,083	9,452	13947	11,727

Maintenance OPI Category	Priority System OPI Scores		Priority System Goal	General System OPI Scores		General System Goal	Priority System Deficiencies		General System Deficiencies		Total Sys. Deficiencies
	04/01/02	03/31/03		04/01/02	03/31/03		04/01/02	03/31/03	04/01/02	03/31/03	04/01/02
Guardrail	6	6	5	4	5	5	52	73	315	251	367
Pavement Deficiency	6	6	5	6	5	5	91	102	256	462	347
Pavement Drop Off	4	5	4	4	4	5	99	67	354	324	453
Vegetation Obstruction	6	5	4	3	3	5	2	18	45	64	47
Litter	5	6	4	0	3	2	3,440	1,319	6,603	3,022	10,043
Drainage Ditch Obstruction	3	5	4	3	3	4	20	10	90	92	110
Sign Deterioration	4	5	5	4	5	4	47	24	208	159	255
Pavement Marking	3	3	3	4	4	5	198	103	332	376	530
Snow & Ice											
Totals							3,949	1,716	8,203	4,750	12,152

Figure 58. *A county work plan show condition, level of effort.*

Deductions					Total Hours Less Deductions	Maintenance Contracts	
All Other Leave		Other Direct Labor		Project Inspection			
04/01/02	03/31/03	04/01/02	03/31/03				
47,399		47,290		6620	156,660		
10,950		1,090		39325	5,956		
3,449		6,428		960	47,153		
61,798	54,143	54,808	62,542	46905	209,769	$4,334,382	$3,411,466

Total TMS Work Effort (Hours)		Total CMS Contract Work Effort	Projected Deficiencies as of March 31, 2003		Projected Date to Meet OPI Goal		TMS Costs for Total System	CMS Costs for Total System	TMS and CMS Costs for Total System	Total System Deficiencies Remaining
Planned	03/31/03	Planned	Priority Sys.	General Sys.	Priority Sys.	General Sys.	03/31/03	03/31/03	03/31/03	03/31/03
12,230	8,723	$1,520,382	123	316	03/03/03	03/03/03	$623,642	$1,121,962	$1,745,604	324
25,701	26,167	$0	290	574	03/03/03	03/03/03	$2,261,133	$0	$2,261,133	564
31,014	34,691	$0	111	399	03/03/03	03/03/03	$2,604,101	$0	$2,604,101	391
19,544	31,375	$0	31	44	03/03/03	03/03/03	$2,327,761	$0	$2,327,761	82
15,313	17,615	$0	4,277	4,013	03/03/03	03/03/03	$920,866	$0	$920,866	4,341
34,672	31,829	$400,00	16	69	03/03/03	03/03/03	$2,319,455		$2,579,726	102
10,096	12,831	$0	38	241	03/03/03	03/03/03	$1,149,795	$0	$1,149,795	183
2,306	1,288	$801,000	90	382	03/03/03	03/03/03	$96,532	$694,406	$790,938	479
11,817	45,797						5,877,910	$0	$5,877,910	
162,693	210,315	$2,721,382					$18,181,196	$2,076,639	$20,257,835	6,466

Figure 59. *A county work plan's anticipated level of effort by category of deficiency.*

Table 30. *Guardrail expenditures and conditions*

Ohio Guardrail Expenditures and Results						
	Goal Priority System	Score Priority System	Goal General System	Score General System	Total Dollars Planned	Total Dollars Expended
2002	4	4	4	4	$15,158,160	$13,033,940
2003	3	6	4	5	$15,305,939	$27,997,339
2004	4	6	4	6	$21,196,440	$24,016,952
2005	4	6	4	6	$11,270,815	$15,884,488
2006	4	6	4	6	$11,970,358	$7,637,011
2007	4	6	4	6	$12,143,049	$10,186,560
					$87,044,761	$98,756,290

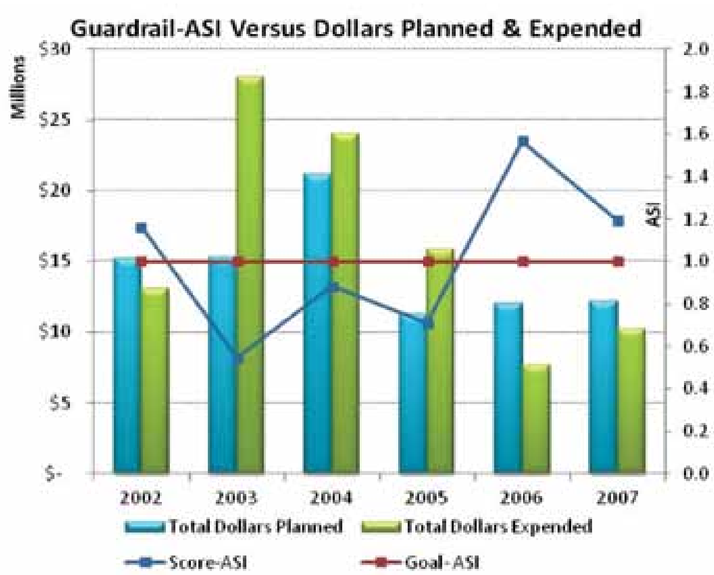


Figure 60. *Ohio guardrail expenditures and conditions.*

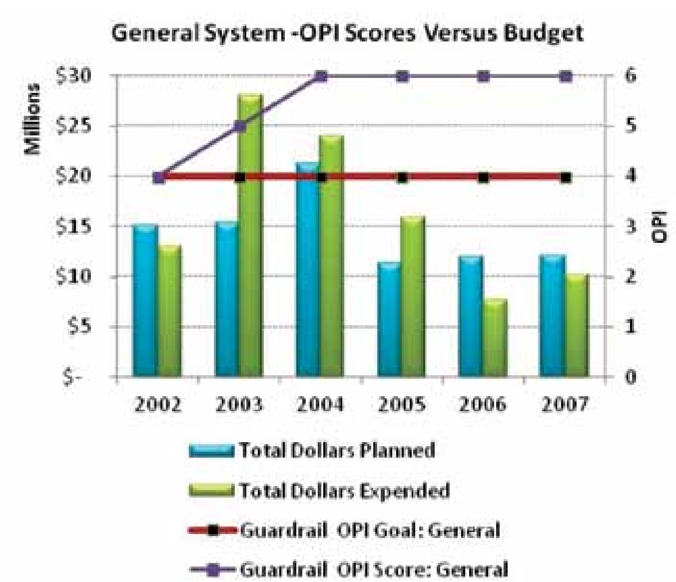


Figure 61. *General system guardrail conditions, budgets.*

The higher expenditures were left as matter of judgment for each district, and most, routinely exceeded the minimum threshold targets.

Figure 60 illustrates the trends and expenditures graphically. It assumes that the "total dollars planned" equates to the "needed" amount that would serve as the denominator in a sustainability ratio. With that assumption, Figure 60 illustrates that while a $15.1 million expenditure would achieve the minimum goal of an OPI score of 4, ODOT overspent that minimum and achieved higher results. Guardrail consistently improved, rising from scores of 4 to scores of 6 for both the Priority and the General System.

As also can be seen, the overall expenditures were reduced after 2004 and ODOT still maintained it highest score of 6. As seen in other examples, the process of accurately forecasting level of effort and budget for maintenance activities often takes several years. It appears that the department and its districts were learning to calibrate the level of effort to sustain the high standards, after an initial surge in investment to clear up backlogs of deficiencies and to achieve the highest OPI scores. Investment fell from a high of nearly $28 million in 2003 down to $10.1 million in 2007 yet the guardrail scores remained high, and well above the minimum goal.

Similar calibration could be seen over time in the category of shoulder drop offs.

As seen in Table 31 and Figure 63, the 2002 score for shoulder drop offs on the Priority System was far below target and for the General System the scores only met the minimum goal of 3. The level of effort was boosted in 2003 with a commensurate rise in shoulder drop off scores on both the Priority and General System. Again, the trend could be seen where following the initial addressing of backlogs, the expenditures on sustaining the conditions steadily fell while retaining the higher scores.
As seen in 2007, the scores were higher than the targets when the expenditures were higher than the planned budget. This could also be the result of additional effort required to repair shoulders after particularly heavy rains.

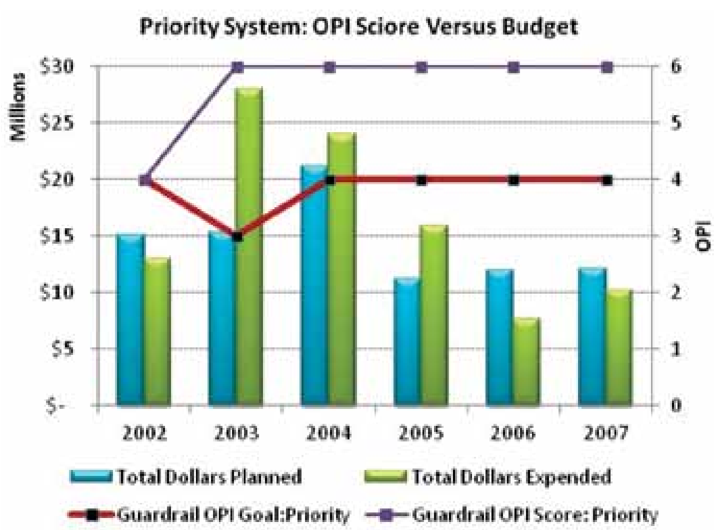


Figure 62. *Guardrail Work-Score, Target and Expenditure.*

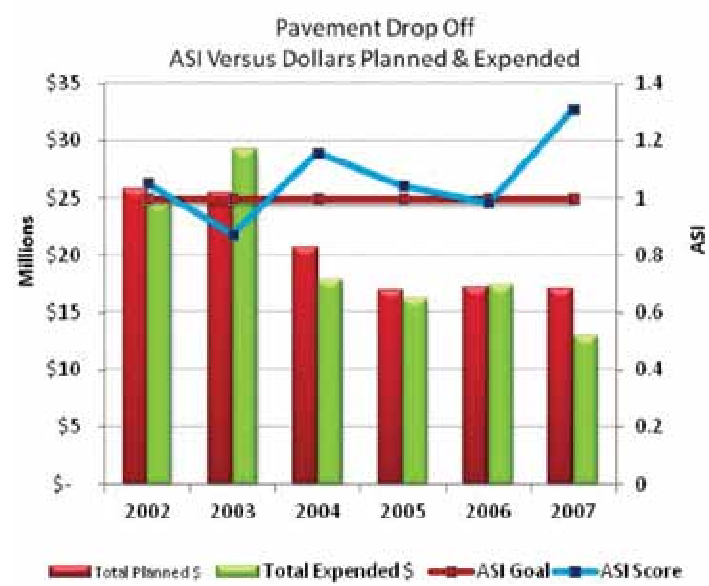


Figure 63. *Shoulder drop off condition, budgets.*

Table 31. *Shoulder drop off conditions, expenditures.*

Ohio Shoulder Drop Off Expenditures and Results						
	Goal - Priority	Score-Priority	Goal - General	Score-General	Total Planned $	Total Expended $
2002	3	1	3	3	$25,797,874	$24,522,219
2003	3	5	3	5	$25,473,871	$29,190,764
2004	4	6	4	6	$20,652,394	$17,846,365
2005	4	6	4	6	$16,910,752	$16,230,485
2006	4	6	4	6	$17,140,249	$17,402,526
2007	4	6	4	6	$7,019,441	$12,980,742

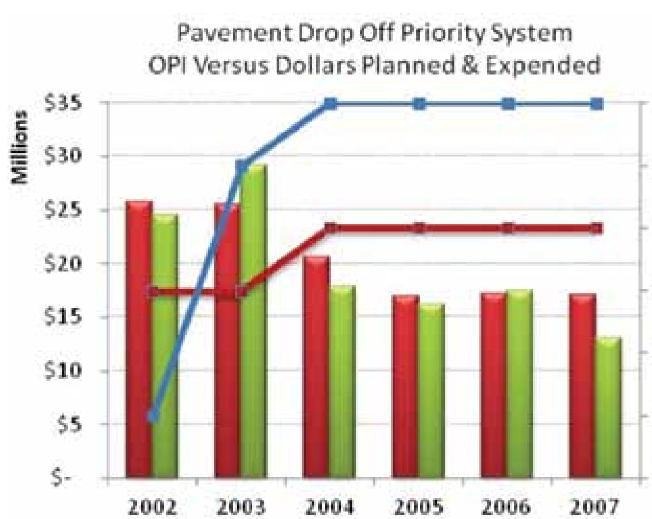


Figure 64. *Drop off conditions, expenditures on Priority System.*

Ohio Conclusion

The data for the other seven Ohio maintenance categories are not illustrated here in the interest of brevity. The two examples of guardrail and shoulder drop offs illustrate that for the Ohio maintenance categories the level of effort necessary to sustain maintenance conditions can be estimated and compared to the actual expenditures to produce maintenance-specific sustainability ratios. The Ohio example also illustrates that the generation of the maintenance ratios is possible without using a commercial maintenance management system software package. In other words, the generation of the maintenance sustainability ratio is possible using several methods and allows flexibility regardless of the State's maintenance management process.

In Ohio's case, the seven categories of maintenance expenditures could be "rolled up" into one composite index that allows for reasonable budgeting certainty that a given level of investment should sustain maintenance conditions indefinitely over the long term. As with the Utah DOT example, however, the Ohio case study illustrates in any given year the needed level of investment by maintenance category may need to exceed the planned amount for several reasons. Flooding, geologic conditions or other events can significantly affect maintenance items such as drainage, shoulder drop offs or even guardrail. As the Utah case study illustrated, the use of a sustainability ratio for maintenance provides long-term insight into needed expenditure levels but it also needs to be augmented with engineering judgment as conditions change based upon in-the-field observations. In the early years of establishing maintenance targets, the actual field conditions and the needed level of investment may not be precise and may need to be calibrated over several years. Likewise, severe weather or other events can cause annual fluctuations in both conditions and in needed expenditures. However, when viewed over a several year period as shown in the Ohio example, the sustainability ratios can augment decision making and can help illustrate how investment levels compare to the optimized investment levels necessary to sustain maintenance conditions over the long term.

North Carolina Maintenance Analysis

Summary

The North Carolina Department of Transportation (NCDOT) uses its Maintenance Management Systems to forecast detailed estimates of the levels of capital and labor necessary to sustain its roadway maintenance conditions. With these estimates, it produces forecasts that are similar to Maintenance Sustainability Ratios and which illustrate the necessary level of effort to sustain maintenance conditions over time.

Background

The NCDOT manages the maintenance activities on a large, sprawling and growing highway network. It manages 79,185 miles of highways, far more than is handled by the average department. Because it manages the local highway network, its span of responsibility is disproportionately large.

NCDOT relies on a mature maintenance management system to help it address the thousands of maintenance condition items for which it is responsible. It has developed targets for 18 major maintenance categories and it measures conditions, activities and budgets for many other maintenance categories that do not lend themselves to targets. Its maintenance management process involves inspecting a statistically valid sample of roadways and measuring the conditions. From those measurements, it calculates the numbers of deficiencies and calculates a level of effort to bring them to targeted levels.

"Maintenance" in the NCDOT vocabulary includes minor pavement and bridge repair and preservation activities, treatment of drainage and culverts, maintaining roadside items such as guardrail and cable barrier, mowing, litter, pavement markings, traffic control devices and other such activities and features. Its maintenance definition is considerably broader than those of Ohio and Utah.

Conditions and Expenditures

NCDOT's annual Maintenance Condition Assessment Report (MCAP) provides the General Assembly and public an assessment of the condition of the highway infrastructure and an estimate of the funding needed to meet and sustain its maintenance targets.

Table 32 is an information-rich summary of the categories of maintenance items tracked, their conditions, and a breakdown of whether the conditions met the targets by three highway systems, the Interstate, Primary and Secondary. As can be seen, four major maintenance categories are tracked, drainage, roadside, traffic and bridge. Within each category, between four and six categories of items are measured.

Table 33 presents a summary of the targets, conditions, expenditures and needs for major maintenance items on the NC Interstate Highway system. Table 33 includes more maintenance items than does Table 32 because it includes items for which a target has not been set. NCDOT's maintenance management system tracks the level of expenditure inclusive of labor, equipment, materials and other costs. It illustrates the level of effort expended for each item, and an estimate of the level of effort needed to achieve the target. From the two, a Maintenance Sustainability Ratio can be calculated

Table 32. *NC maintenance conditions and targets.*

Roadway Conditions			Interstate		Primary		Secondary	
			2010	State Average	2010	State Average	2010	State Average
		Performance Measures	Target	Score	Target	Score	Target	Score
Drainage	Unpaved Shoulders	No dropoffs greater than 3 inches and no shoulders higher than 2 inches	95	91	90	89	85	91
	Ditches (Lateral Ditches)	No blocked, eroded or non-functioning ditches	95	98	90	94	85	94
	Crossline Pipe (Blocked)	Greater than 50% diameter open	95	87	90	78	85	74
	Crossline Pipe (Damaged)	No damage or structural deficiency affecting functionality	95	93	90	95	85	91
	Curb & Cutter (Blocked)	No obstructure greater than 2 inches for 2 feet	95	97	90	96	85	96
	Boxes (Blocked or Damanged)	Grates and outlet pipe conditions	95	82	90	87	85	85
Roadside	Vegetation (Brush & Tree)	Freeways, 45 feet from travelway; 5 feet behind guardrail. Not blocking signs. Non-freeways 15 feet over roadway and 10 feet back of ditch centerline or shoulder point	90	90	85	85	80	80
	Vegetation (Turf Condition)	Areas free of erosion	95	84	90	83	85	86
	Stormwater Devices	Functioning as designed	90	94	90	94	90	94
	Landscape Plant Beds	Achieving score of 2 or higher on inspection form	90	90	80	90	N/A	N/A
	Rest Areas & Welcome Centers	Condition rating of 90	90	96	90	95	N/A	N/A
Traffic	Long Line Pavement Markings	Present, visible	90	93	85	90	80	81
	Words and Symbols	Present, visible	90	73	85	85	80	77
	Pavement Markers	Present and reflective	90	84	85	59	N/A	N/A
	Ground Mounted Signs	Visible and legible	90	94	85	91	85	85
	Overhead Signs	Visible and legible	90	93	85	80	85	100
Bridge	NBIS Culverts	Conditon Rating >=6	85	86	85	86	85	89
	Non-NBIS Culverts	Condition Rating = Good	80	84	80	74	80	56
	Overhead Sign Structures	Condition Rating = Good	95	95	95	93	95	88
	Totals		91.27	89.79	87.28	86.04	84.49	85.04

Table 33. *NC Interstate maintenance condition, budget and need.*

Interstate Highway Element			2010 TARGET	State Average Score	FY 2010 Expenditure	Funding Required to attain and maintain LOS	Expenditure by Category	Need by Category	Ratio by Category
SHLD/DITCH	RM-1	High/Low Shoulder	95	91	$1,190,679	$2,237,430	$1,468,462	$2,515,213	0.584
	RM-2	Lateral Ditches	95	98	$277,783	$277,783			
DRAINAGE	RM-3	Crossline Pipe (Blocked) < 54"	95	87	$17,065	$48,449	$942,691	$3,767,723	0.250
	RM-4	Crossline Pipe (Damaged) < 54"	95	93	$39,699	$56,774			
	RM-5	Curb & Gutter (Blocked)	95	97	$601,328	$601,328			
	RM-6	Drop Inlets, CB's, etc (Blkd/Damaged)	98	82	$284,599	$3,061,171			
ROADSIDE APPURT		Guardrail/Cable/Median Barrier/Conc		Not Rated	$1,543,609	$1,543,609	$1,795,609	$1,795,609	1.000
		ROW Fence		Not Rated	$246,836	$246,836			
		Impact Attenuators		Not Rated	$5,165	$5,165			
ROADSIDE	R-1	Brush & Tree Control	90	90	$4,305,375	$4,305,375	$10,807,951	$14,093,842	0.767
	R-2	Turf Condition	95	84	$583,791	$2,004,194			
	R-3	Stormwater Devices (NPDES)	90	90	$5,933	$5,933			
		Uncontrolled Growth		Not Rated	$1,050,224	$1,050,224			
		Mowing		Not Rated	$2,861,847	$2,861,847			
		Litter & Debris Control		Not Rated	$2,030,780	$3,866,268			
TRAFFIC	T-1	Long line pavement markings	90	93	$301,387	$301,387	$1,721,914	$1,885,077	0.913
	T-2	Words % Symbols	90	73	$46,533	$154,897			
	T-3	Pavement Markers	90	84	$76,718	$131,516			
	T-4	Signs ground	90	94	$1,236,758	$1,236,758			
	T-5	Overhead Signs	92	93	$60,518	$60,518			
PVMT	P-2	Asphalt pavement repair	95	89	$1,225,568	$2,872,142	$1,420,011	$3,066,585	0.463
	P-3	Concrete pavement repair	95	Not Rated	$194,443	$194,443			
		TOTALS			$18,156,639	$27,124,049	$18,156,639	$27,124,049	0.669

for each item, for each year, as shown in the far right column of Table 33.

Although Table 33 illustrates only the Interstate Highway System, similar analyses are conducted for the Primary and the Secondary System. Such analysis provides a high degree of granularity for the highway network, by maintenance category, or even district.

The total maintenance needs are "rolled up" into estimates as shown in Table 34 (see next page).

It illustrates the forecasts of financial needs to meet maintenance targets for seven years. From this forecast, a Maintenance Sustainability Ratio can be calculated once budget amounts are approved for each of the seven years. Future budgets are not yet approved.

Legislative Reporting

The maintenance analysis above is part of a larger North Carolina asset management reporting process that also includes pavement and bridges. The

Table 34. *Forecasted need by category for performance-based activities.*

Performance Based Activities	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Pavements	$299.03	$311.59	$324.68	$338.31	$352.52	$367.33	$382.76
Shoulders & Ditches	$63.19	$65.84	$68.61	$71.49	$74.49	$77.62	$80.88
Drainage	$39.13	$40.77	$42.49	$44.27	$46.13	$48.07	$50.09
Roadside Appurtances	$9.23	$9.62	$10.02	$10.44	$10.88	$11.34	$11.81
Traffic Control Devices	$40.08	$41.76	$43.52	$45.35	$47.25	$49.23	$51.30
Roadside/Environmental	$103.01	$107.34	$111.84	$116.54	$121.44	$126.54	$131.85
Rest Area/Welcome Center Maint	$11.70	$12.19	$12.70	$13.24	$13.79	$14.37	$14.98
Plant Bed Maintenance	$5.07	$5.28	$5.50	$5.74	$5.98	$6.23	$6.49
Total	$570.44	$594.40	$619.36	$645.38	$672.48	$700.73	$730.16

reports provide quantitative and qualitative descriptions of the system including:

1. The annual cost to meet and sustain the established performance standards for the highway system to include (i) routine maintenance and operations, (ii) system preservation, and (iii) pavement and bridge rehabilitation.

2. Projected system conditions and corresponding optimal funding requirements for a seven-year plan to sustain the performance standards.

Three comprehensive surveys are used to evaluate the condition of the highway system, a Maintenance Condition Survey, a Bridge Condition Survey and a Pavement Condition Survey. In keeping with the legislative requirements, NCDOT estimates the cost to meet and sustain these performance standards and it forecasts the optimal funding needed for the seven year period.

For instance, it notes that the annual cost to meet the roadway maintenance performance standards is $668.47 million. The cost to meet the bridge performance standards is $71.65 million and to perform necessary bridge preservation functions is an additional $26.24 million. The cost to operate the State's traffic signals and Intelligent Transportation System (ITS) devices is $74.49 million. The annual cost for routine and interstate pavement preservation activities is $207 million and resurfacing is an additional $330 million annually.

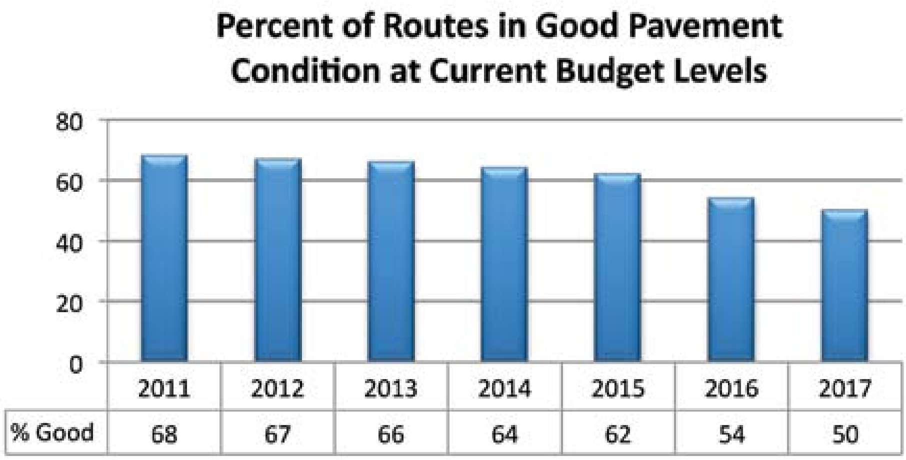
These projected investment needs are totaled, after some adjustments for non-traditional funds, to create total maintenance funding needs for fiscal year 2011–2012 of $1.26385 billion. This need is in contrast to an estimated allocation of $933 million. Superficially, this analysis provides the initial inputs for an Asset Sustainability Index of:

$$\frac{\$933}{\$1{,}264} = 73.8$$

In other words, approximately 74 percent of the investment necessary for long-term sustainability of the network is provided. Although the NCDOT report does not produce an actual ASI, its narrative and its interpretation provide policy makers with the bottom line of the long-term consequences. "North Carolina stands at a crossroads of funding and system condition. The Department recognizes that as funding has remained constant system condition decreases, possibly jeopardizing the safety and mobility of North Carolina's citizens. A comprehensive, balanced funding program of maintenance preservation, rehabilitation and replacement is necessary to operate and maintain the highway system at an acceptable level."

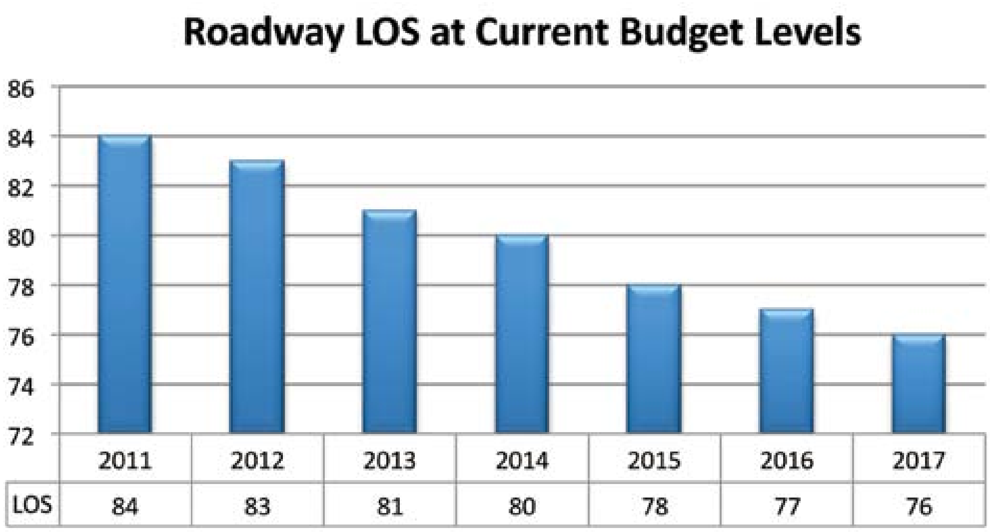
Additional forecasts provided by the NCDOT report illustrate the future system consequences if the current investment levels continue.

Figures 65 and 66 illustrate that pavements and overall composite conditions will decline with the



	2011	2012	2013	2014	2015	2016	2017
% Good	68	67	66	64	62	54	50

Figure 65. *Forecasted pavement conditions at current budget levels.*



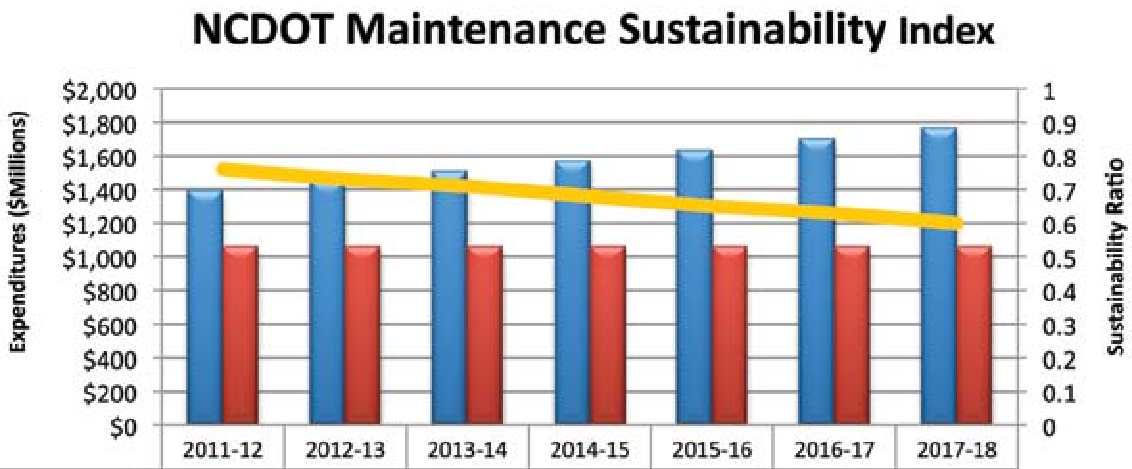
	2011	2012	2013	2014	2015	2016	2017
LOS	84	83	81	80	78	77	76

Figure 66. *LOS forecast.*

percent of routes with "good" pavement conditions falling from 68 percent to 50 percent. NCDOT calculates an overall Level of Service or LOS based upon a composite of several condition factors. It forecasts that overall LOS will decline from 84 to 76 by 2017, on a scale of 0-100.

An overall composite Asset Sustainability Index is calculated in Figure 66 forecasted through 2017–2018. It illustrates that if current funding conditions remain static at 2010 levels, the overall department's ASI will fall from .76 to .60 by 2017–2018. Nearly $770 million additional would be needed to achieve the optimal ASI of 1.0 in 2017–2018.

Care must be used in comparing the results of Figure 67 from seemingly comparable ASI and Pavement Sustainability Ratios cited earlier in the Ohio or Utah examples. Each State uses different definitions and categories of assets and expenditures so that they do not readily compare from State to State. In the earlier Ohio example, the analysis focused entirely on the State and Federal aid highway system, while in North Carolina it



	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Maintenance Needs	$1,393	$1,448	$1,507	$1,568	$1,632	$1,699	$1,769
Budget	$1,063	$1,063	$1,063	$1,063	$1,063	$1,063	$1,063
Sustainability Index	0.76	0.73	0.71	0.68	0.65	0.63	0.6

Figure 67. *NC ASI for maintenance categories, expenditures.*

includes thousands of miles of local routes. Also, North Carolina uses very different budget categories than does Ohio or Utah. For instance, the resurfacing and reconstruction needs of the North Carolina Interstate Highway System are not included in these calculations. That system's long-term preservation is largely addressed through the federally funded State Transportation Improvement Program (STIP) projects using funds not eligible for the local routes.

As stated in the opening chapter, the intent of this report is to illustrate the proof of concept of the ASI and to illustrate how it can provide policy makers with enhanced understanding of the needed levels of investment required to sustain the highway system into the future. Although, the North Carolina budget categories and asset class definitions vary considerably from the other case study States in this report, its extensive asset management systems and sophisticated budgeting process provides the data to produce an ASI that is germane to North Carolina policy makers. Its policy makers are responsible for the local routes and therefore are interested in analysis of them. The North Carolina commission and legislators can see from the results of Figure 67 and the supporting data what the long-term consequences for the transportation system will be. NCDOT has appropriated to it approximately $1.063 billion in 2012 for total maintenance and preservation needs. By 2017–2018, the budget should increase to $1.769 billion if the State wants to achieve its highway system condition targets. Such analysis allows policy makers to understand not only how the physical conditions of the highway system are likely to degrade, but also they can calibrate the likely levels of investment necessary to forestall the degradation.

CHAPTER 7

Combining Ratios into an Index

The Asset Sustainability Index provides a few critical measures that summarize the long-term trends facing the transportation system while also allowing "drilling down" into the details of how various asset classes will perform into the future. As a result, inherent in the sustainability metrics is a "nested" series of measures from the most summarized down to the most granular that illustrate specific asset classes, even down to the regional level.

This section will discuss how the Asset Sustainability Index is assembled from the various components. Chapter 10 will discuss further how the summarization and the granularity can help illustrate important aspects of transportation system need.

Highest-Level of Indices

With the Asset Sustainability Index comprising the ratios of pavement, bridge and roadway maintenance, the concept of how to compile them into a composite index is relatively straightforward. The values of the three major ratios are combined and a weighted index is computed.

A simple, theoretical example is shown in Table 35. The amount needed for pavement investment is $500 million, the needed amount for bridges is $250 million and the roadway maintenance need is $225 million. Each is shown as one year's component of a 10-year asset management plan to sustain the assets over the 10-year horizon. Each of the three has a different Sustainability Ratio, with maintenance and bridges receiving a higher percentage of their overall need than do pavements. The weighted sustainability index is the simple weighted average of the three Sustainability Ratios combined into one overall Sustainability Index. In this example, the Sustainability Index for this one year is .88.

Figure 68 illustrates how the insight provided by the ASI increases when placed in a time series. Any individual year's index provides only limited insight but the decade-long trend line provides insight into the consequences over time.

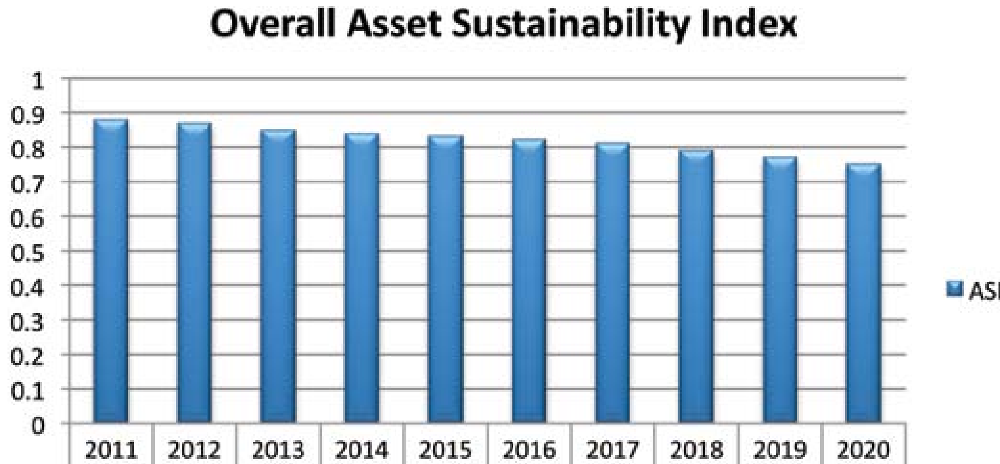
Figure 68 conveys the overall trend that statewide investments are inadequate and the current level of investment does not lead to sustainable highway assets over the long term. It also shows that by 2020 investment is only 75 percent of need, which illustrate the approximate magnitude of needed additional investment.

Uses of the Index

An image such as Figure 68 can be added to key planning and budgeting documents to provide one, comprehensive metric that summarizes the direction in which the highway conditions are heading if

Table 35. *Calculation of a Sustainability Index.*

	Budgeted Investment	Needed Investment	Calculation	Sustainability Ratio	Sustainability Index
Pavement	$415	$500	$415/500	0.83	
Bridge	$225	$250	$225/250	0.90	
Maintenance	$214	$225	$214/$225	0.95	
Total	**$854**	**$975**	**$854/$975**		**0.88**
Millions$					



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ASI	0.88	0.87	0.85	0.84	0.83	0.82	0.81	0.79	0.77	0.75

Figure 68. *ASI over time.*

current spending continues. The ASI also illustrates the magnitude of needed additional investment. Research such as the National Cooperative Highway Research Program 14-34 *Communicating the Value of Highway System Maintenance and Preservation* is examining the struggle that highway agencies have in reaching stakeholders with understandable, yet convincing, information about the need for investment. Most transportation management systems produce credible reports but ones that are developed for well-informed and highly trained transportation practitioners. Converting management system information into formats useful for lay audiences is a continuing challenge. Data such as International Roughness Index scales or descriptions of bridge functional obsolescence have proven difficult to explain to the media and others.

The index also can help satisfy calls for accountability and performance measurement. To date, most highway condition performance measures have been narrowly focused upon specific assets, or even only characteristics of specific assets. IRI measures provide insight into pavement roughness, but not into pavement structure, skid quality or remaining service life. Likewise, a bridge may be rated structurally "fair" today but may be on the verge of decline into a "poor" rating that creates need for imminent investment. Providing metrics about these individual characteristics yields insight into condition performance, but only for narrow components of the highway network, and generally only for current conditions. The ASI provides an overall picture for whether the asset management needs for the system as a whole are being adequately addressed.

Details for Greater Understanding

As a composite metric, the ASI sits at the apex of a comprehensive asset management analysis. It summarizes in one metric the adequacy of investment necessary to sustain highway infrastructure conditions for future users.

Because the ASI is a "condensed" measure, it also allows for the disaggregation or the "drilling into" of its components for greater understanding as to the consequences of under-investment. As the components of the ASI are examined, it is possible to understand which assets are under-funded, and by how much. The final ASI is actually the weighted average of a series of component sustainability ratios each braided into a composite. Each strand can be examined separately to illustrate the tradeoffs that have been made and the consequences of them. The granularity that the detailed analysis provides allows decision makers to understand how to calibrate additional investment to achieve very specific results—those results being an adequately funded highway program that sustains all asset classes at a steady state of acceptable conditions.

Nearly every highway agency in the United States today faces serious unmet needs. Officials in these agencies make difficult tradeoffs to allow some assets to decline in condition so that they can focus investments on even more pressing needs. Such tradeoffs were evident in the Minnesota and Utah examples where officials in both States reluctantly decided to allow rural pavement conditions to decline in order to sustain conditions on higher functional classes. The granularity of the ASI allows for the drilling into its components to illustrate which asset classes are being underfunded and by approximately how much.

In the case studies of Utah, Ohio, North Carolina and Minnesota, considerable time was spent illustrating sustainability ratios for critical asset classes such as guardrail, pavement markings or rural pavement conditions. These individual asset classes represent a minority of overall spending but are very important individually. Items such as guardrail or pavement markings contribute disproportionately to highway safety. Their importance can belie the relatively small percentage they consume of the agency's overall spending.

In the hypothetical case shown in Table 36 the maintenance sustainability ratio is .95, indicating that most maintenance needs are addressed. However, if within that overall maintenance calculation key components such as guardrail or pavements markings are under-funded and deteriorating, key public safety and infrastructure trends could go unreported. Likewise, the case studies of both Utah and Minnesota illustrated that rural pavement conditions are likely to significantly deteriorate as scarce resources are prioritized for higher value assets such as the Interstate Highway System or bridges. In Ohio's case, inordinately high bridge deficiencies within districts were observed even though statewide average conditions met targets.

Table 36 from the NCDOT case study illustrates how that DOT has determined need with significant granularity for its bridge maintenance activities. This determination of need can be compared to budgeted amounts per item to produce significant insight into which categories of bridge needs are being adequately met, and which are not. With such granularity, overall decision making and public reporting can be improved. Also, such granularity can be used to prioritize where additional investment is most needed.

Similar granularity was apparent from the other States, as well. Utah displayed considerable detail by individual class of maintenance asset, further disaggregated by region. Ohio detailed bridge condition deficiencies by category, by district and by year. The granularity of the modern management systems allows the agencies to convey to policy makers the trade-offs faced when investment levels are inadequate and which asset classes must be allowed to deteriorate in order to put resources into even more acute areas.

Table 37 (see next page) illustrates how the information from the hypothetical scenario in Table 35 can be portrayed with greater granularity to clarify which assets classes are most adequately funded and which are the least. As can been seen in Table 37, the major categories of Pavements, Bridges and Maintenance are further broken into subcategories by major asset class. The sustainability ratios of the

Table 36. *NCDOT bridge maintenance need by category.*

Performance Based Activities	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Pavements	$299.03	$311.59	$324.68	$338.31	$352.52	$367.33	$382.76
Shoulders & Ditches	$63.19	$65.84	$68.61	$71.49	$74.49	$77.62	$80.88
Drainage	$39.13	$40.77	$42.49	$44.27	$46.13	$48.07	$50.09
Roadside Appurtances	$9.23	$9.62	$10.02	$10.44	$10.88	$11.34	$11.81
Traffic Control Devices	$40.08	$41.76	$43.52	$45.35	$47.25	$49.23	$51.30
Roadside/Environmental	$103.01	$107.34	$111.84	$116.54	$121.44	$126.54	$131.85
Rest Area/Welcome Center Maint	$11.70	$12.19	$12.70	$13.24	$13.79	$14.37	$14.98
Plant Bed Maintenance	$5.07	$5.28	$5.50	$5.74	$5.98	$6.23	$6.49
Total	$570.44	$594.40	$619.36	$645.38	$672.48	$700.73	$730.16

Table 37. *Sustainability ratios over time by asset class or activity.*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pavements	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.77	0.76
Major Routes	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.74	0.73
Arterials	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Collectors	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Pavement Rehabilitation/Replacement	0.40	0.40	0.39	0.39	0.38	0.38	0.38	0.37	0.37	0.37
Pavement Preventive Mainenance	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Bridges	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82
Preventive Maintenance/Preservation	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82
Sub and Superstructures	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79
Decks	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82
Painting	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Maintenance	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Guardrail	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Pavement Markings	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Drainage	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Signage	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Vegetation/Roadside	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Pavement Surfaces	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Overall ASI	0.88	0.87	0.855	0.84	0.83	0.82	0.81	0.79	0.77	0.75

individual classes are shown, and are aggregated in the bottom line into an Asset Sustainability Index for this hypothetical roadway network. The tradeoffs made by the highway agency are clear with the color coding. Green cells indicate adequate investment rations while ones in red indicate the degree of underfunding. In this scenario, Pavement Rehabilitation and Replacement is underfunded acutely throughout the forecast period. Asset classes of resurfacing of major routes, bridge sub and superstructure repair, bridge preventive maintenance and bridge decks are scheduled for significant declines in investment levels as compared to their needs.

Although Table 37 is theoretical, it very closely approximates the type of analysis that was "teased out" of the data from the transportation departments in Utah, Minnesota, Ohio and North Carolina. An actual analysis that resembled Table 37 would give a policy-maker an at-a-glance summation of the adequacy of investment by major asset class for each year of the next decade.

Summary

Both granularity and summarization are possible with an indicator such as the ASI and its related metrics. It translates diverse asset performance indicators into a common denominator of investment adequacy. The ASI and its related metrics can be summarized into one overarching metric for the entire network through a simple weighted average calculation. At the same time, summary tables such as Table 37 allow the drilling down into asset classes or even geographic regions to further clarify the impacts of underinvestment. The type of granularity displayed by the States examined in this report allow them to specify to policy makers which asset classes are underfunded, and what the long-term implications of that are likely to be. Likewise, the asset-class analysis those States displayed allows creation of Sustainability Ratios for individual asset classes that can add increased insight into understanding of highway asset condition trends.

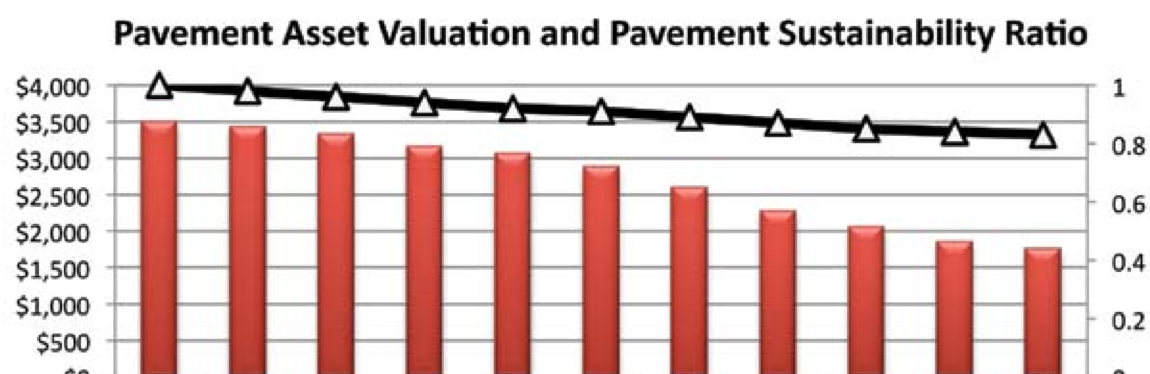
CHAPTER 8

GASB 34 Precedents

The Asset Sustainability Index and its related ratios are considered in this report as evolutionary next steps to further enhance the reporting of transportation asset management needs and issues. The practice of TAM has steadily evolved from the mid-1990s in the United States and has at several points of its development intersected with other important reporting frameworks. One such intersection is with the Governmental Accounting Standards Board Statement 34 (GASB 34.) GASB 34 went into effect in 2001 and represented a major change in government accounting for infrastructure.

The Asset Sustainability Ratio represents a complementary mirror image of the GASB 34 reporting process. While the ASI is forward looking, the GASB 34 reports are backward looking. They report upon past changes in highway asset values, conditions and expenditures. If the two were reported in a coordinated fashion, they could provide a long-term perspective on where infrastructure conditions have been and where they are heading. The GASB reports would provide a 10-year summary of changes in asset values and expenditures while the ASI forecasts would provide a similar projection into the future.

Figure 69 is repeated from Chapter 1 to illustrate the long-term perspective that could be provided by combining GASB 34 reports of past trends with ASI forecasts of likely future conditions. As seen in Figure 69, the Asset Valuation of the theoretical rural pavement network is shown as having declined from 2000 to the present. This is the type of information that can be produced from the lagging GASB 34 reports. Looking forward from 2011 to 2019, the forecast illustrates that the decline in asset value is expected to increase and that the level of necessary investment has fallen from nearly 100 percent to a low of 83 percent, or a Pavement Sustainability Ratio of .83. Commensurately, the



	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2019
Asset Valuation	$3,500	$3,430	$3,328	$3,163	$3,069	$2,886	$2,605	$2,278	$2,056	$1,855	$1,762
PSR	1	0.98	0.96	0.94	0.92	0.91	0.89	0.87	0.85	0.84	0.83

Figure 69. *Theoretical Pavement Sustainability Ratio and corresponding asset valuation.*

value of the rural pavement network has declined from $3.5 billion to only $1.76 billion. In other words, this theoretical State has lost half of the value of its rural highway network pavements.

Currently, the GASB 34 reports don't provide this type of granular insight for individual asset classes, such as rural pavements, for reasons that are discussed below. However, the evolution of the sustainability ratios could provide an evolutionary next step to further enhance the value of the existing GASB 34 processes.

GASB 34 History

The GASB 34 standards were intended when adopted in 1999 to provide new insights into whether U.S. public agencies were accruing future liabilities in the form of deteriorated assets. Among the objectives of GASB 34 was to improve public decision making by treating long-term capital assets such as highways as items to be reported on an agency's balance sheets. If the assets were deteriorating at a faster rate than they were being repaired, it would create a long-term liability that should be disclosed in annual financial reports. GASB 34 also emphasizes Asset Valuation, or the assignment of monetary value to infrastructure assets. The concept is that if roadway elements are described as public assets and valued in monetary terms, the public imperative to preserve them in sound condition is enhanced.

The 1999 standards added a new requirement for agencies to include a clear non-technical Management Discussion and Analysis (MD&A) addressing basic facts regarding whether the infrastructure conditions were improving, declining or sustaining. The MD&A was to report, among other things, significant changes in the assessed condition of assets from earlier assessments, how conditions compare to targets, and any significant differences between what was budgeted to be invested in preservation from what actually was spent.

This concept in U.S. public accounting represented at the time a major shift in focus. In the past, accounting reports represented only short-term balances of accounts for the current year, or biennium. As the GASB guidance made clear, snapshots of short-term account balances provide the public or policy makers little insight into whether current investment levels and maintenance practices are sufficient to ensure the long-term performance of major infrastructure. As the GASB 34 guidance explains "….the citizenry, legislative and oversight bodies, and investors and creditors, also need information about the probable medium- and long-term effects of past decisions on the government's financial position and financial condition. Without that information, these groups cannot assess the probable effect of current-period activities on the future demand for resources, or whether the government can continue to meet its service objectives and financial obligations in the future." GASB guidance at the time summarized the rationale for the reporting standards in the following way. "In short, the new annual reports should give government officials a new and more comprehensive way to demonstrate their stewardship in the long term in addition to the way they currently demonstrate their stewardship in the short term through the budgetary process."[8]

GASB 34 as an auditing framework was intended to complement other frameworks such as asset management by focusing upon the financial implications of the results, or lack thereof of these other systems. Government auditing agencies play a fundamental role in public governance. They ensure compliance with financial laws and reporting standards, and by doing so, provide public transparency by ensuring the accuracy and completeness of agency financial reports. The GASB 34 requirements cast the analytic results of the other management systems and practices into a format suitable for satisfying the fiduciary requirements of audit statutes and agencies. GASB 34 requirements also were expected to play an important financial role when agencies seek bond ratings. Bonding agencies seek long-term stability, or sustainability, in an agency's finances before awarding a sound bond rating. Based on that rating, bond investors can be assured they are highly likely to be repaid and that the agency is operating in a fashion that ensures its financial soundness for many years, often up to 30 years in the case of some bonds.

In 2008, NCHRP Report 608, "GASB 34: Methods for Condition Assessment and Preservation," examined how States were implementing the GASB 34 standards. It reported that States that were strong practitioners of TAM tended to have robust GASB 34 reports, while those that were not tended to have more perfunctory depreciation reports.[9] Agencies have two ways to report. The first approach is the depreciation method which generally applies "straight line" depreciation to categories of assets and assigns a value to the depreciation. The value of the depreciation is compared to what is spent on infrastructure preservation to determine if preservation expenditures are adequate. The second approach, the modified approach, is more sophisticated and generally relies on more detailed comparison of expenditures and depreciation. In the modified approach, the agency's management systems often provide condition and depreciation information that is more robust.

The GASB 34 requirements call for the Management Discussion and Analysis to be included in the agency's annual Comprehensive Annual Financial Reports (CAFR.) These were envisioned to serve like a publicly traded corporation's annual report to shareholders. They would allow the public to understand the long-term health of the infrastructure and understand the long-term consequences of current investment decisions.

However, the transportation agencies interviewed in NCHRP 608 reported that their CAFRs received little attention and had become "just one more administrative task." "We also find that the agencies report that they receive very little interest in this information from outside entities such as legislative bodies, the investment community or the general public. It was widely hoped that provision of this information would spark interest in the condition and preservation of infrastructure assets—the factors that seem to have precluded interest are discussed in this report."

A review of NCHRP 608 and several of the individual State CAFRs reveal several reasons for the possible lack of interest in the CAFRs.

First, many of the CAFRs reviewed for this report read like accounting reports which are heavily laden with tables of numbers and accounting categories that do not explicitly state whether roadway conditions are declining or improving.

Secondly, the value of assets are grouped in ways that tend to obscure whether particularly important asset classes are improving or degrading. For instance, the overall value of highway assets includes the value of new construction and the underlying land, earthworks and buildings owned by the State. These categories increase the value of overall assets and tend to mask the decrease in value of key asset categories, such as pavement surfaces, bridge decks or maintenance appurtenances such as signage. The actual value of pavement surfaces or bridge decks are not reported separately and their decreasing asset value is offset when the value of new construction is included in the asset base value.

Third, several states set lower threshold values for GASB 34 targets than they set for their internal asset management targets. The result is that lower levels of expenditures are needed to prove "sufficiency" in GASB reports. While a State may strive for 90 percent achievement of pavement targets as an asset management goal, it may set a target of 80 percent for its GASB target. Only a careful reading of the asset management reports compared to the CAFR will identify why the CAFR reports targets are met while the asset management reports indicate that asset conditions are declining. One State produced a pavement forecast report that reported substantial declines expected in its pavement conditions. However, the State's CAFR reported pavement targets were met. Also in some states contacted, the asset management staff did not coordinate with the finance staff that produced the agency's CAFR.

Fourth, and related to the third issue, is that if a State fails to meet a GASB condition target the GASB rules state it should shift from using the more sophisticated "modified approach" to the less sophisticated "depreciation approach." Therefore, the states that want to retain the more robust reporting process face a disincentive if they candidly report that asset condition targets are not met.

Fifth, the CAFRs of some states address only two to three years, preventing long-term trend lines of asset conditions from being apparent. A reader would need to review multiple years of reports in order to understand the long-term asset-condition trends.

Sixth, the CAFRs are inherently backward looking and do not include forecasts. Therefore, only assumptions of future performance can be inferred from them.

Seventh, the GASB rules do not allow the investment of many asset replacements to be added as capital, but instead say they must be treated as an expense. For instance, if an existing deteriorated bridge is replaced with a new bridge, the new bridge is not included as new, increased "capital" or "equity" but rather must be reported as an expense. The transportation officials interviewed in NCHRP 608 disagreed with this GASB interpretation because it causes the agency's investment in infrastructure renewal to be understated.

Although the GASB 34 requirements were developed to raise public understanding of and interest in infrastructure conditions, they had not appeared to have done so to the extent hoped for in 2001.

Some State's CAFRs do provide a long-term perspective regarding asset conditions and expenditure levels. For instance, the Kansas Department of Transportation provides information showing that pavement and bridge condition targets are being met, that minimum investment levels have been largely achieved and that overall asset values have increased.

For instance, it notes that minimum pavement conditions for Interstate Highway and non-Interstates have continually surpassed minimum targets, as seen in Table 38.

The Kansas DOT reports (Table 39) that net assets, including the value of highway assets, have risen 22 percent in nine years and that expenditures for roadway maintenance, preservation and expansion have increased 34 percent.

These types of reports do serve the function of indicating that the departments are reasonably able to meet their infrastructure needs, they have grown the State's assets and that performance targets are being met.

A possible enhancement to the GASB 34 reports could be further granularity in reporting for critical asset classes, such as illustrated in Figure 69. Such granularity could disaggregate the effects of investment and allow greater understanding whether overall asset values were rising because of sound infrastructure investment in existing assets or if asset values are rising because of adding new highway facilities. The adding of new facilities increases long-term maintenance costs. The granularity of asset valuation change by asset class could increase understanding of whether critical roadway assets are increasing or decreasing in value.

Table 38. *Kansas DOT GASB data.*

Pavement Conditions and Expenditures				
	Interstate Miles		**Non-Interstate Miles**	
	Minimum Acceptable Condition	Actual Condition Level	Minimum Acceptable Condition	Actual Condition Level
2008	80	96	75	85
2009	80	97	75	86
2010	80	97	75	86
	Estimated Expenditures to Maintain System at Minimum Acceptable Condition	Actual Expenditure	Estimated Expenditures to Maintain System at Minimum Acceptable Condition	Actual Expenditure
2006	$110,000	$115,820	$260,000	$390,988
2007	$110,000	$62,935	$260,000	$384,627
2008	$110,000	$68,654	$260,000	$363,582
2009	$110,000	$67,603	$260,000	$392,237
2010	$110,000	$54,807	$260,000	$335,108
(Amounts in Thousands$)				

Table 39. *Kansas highway asset values.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	Change
Net Assets	$8,455,364	$8,543,320	$8,585,739	$8,757,169	$8,932,372	$9,270,951	$9,518,480	$9,986,964	$10,337,675	22%
Maintenance, Preservation, Expansion and Related Expenses	$1,080,294	$1,082,568	$1,182,808	$1,227,139	$1,242,339	$1,259,426	$1,260,003	$1,268,474	$1,443,590	34%
(Amounts in Thousands$)										

CHAPTER 9

Methods for Calculating Need

The case studies and examples cited in this report came from large State transportation agencies that have mature, sophisticated asset management systems. However, such systems are not required to generate sustainability ratios, particularly for smaller governments that manage smaller roadway networks. Credible sustainability ratios could be produced using at least three methods, two of which do not require commercial management systems. Although, those management systems are highly desirable they are not mandatory to produce sustainability metrics. Lack of them should not preclude a government agency from the ability to generate a credible asset sustainability index or its related ratios.

At least three methods for generating asset sustainability metrics will be described very generally. These descriptions are not intended to provide step-by-step guidance but instead only to illustrate that currently such methods are in use in the United States and have routinely produced the inputs that could be used to generate an ASI. The three methods are:

- Using the outputs from modern pavement, bridge and maintenance management systems to generate the needed levels of investment by asset class. Utah and North Carolina use such systems to produce the analyses seen in this report.

- Using data bases and spreadsheets to replicate some aspects of the management systems to the extent that deterioration curves are applied to existing assets and their future conditions are forecast. These forecasts produce estimated levels of treatments that would be required to sustain conditions. The levels of effort are multiplied by known unit costs of treatments to generate the financial need. This very generalized description can be relatively simple and be based on only a few asset classes and few deterioration curves: or it can be much more detailed with multiple asset classes, many deterioration curves and multiple iterations of applying treatment types to generate need and costs. The ODOT uses such a method but it is migrating toward the use of commercial management systems such as those used in Utah and North Carolina.

- Simplified application of depreciation to classes of assets as described in the GASB 34 guidance for agencies using the depreciation, versus modified, method of reporting. This method would apply generalized depreciation rates to major asset classes to determine the level of estimated annualized depreciation they experience. This depreciation is totaled and compared to the amounts actually invested in infrastructure preservation annually to determine if it is adequate. This method is commonly used by U.S. turnpikes to satisfy bond holders and rating agencies that they are investing adequately to sustain their roadways. Similarly, these simplified methods could produce "rule of thumb" investment estimates that would be appropriate to a smaller network, such as a small city or county. Although lacking in detail, they do provide benchmarks of needed investment over the long term.

Use of Management Systems

Among the many advantages of modern pavement, bridge and maintenance management systems is their ability to produce relatively quickly a number of credible investment scenarios. They can produce pavement, bridge or maintenance programs that can be iterated on major criteria such as the amount of available revenue, the desired level of service, by treatment priorities or by combinations of the three. Such flexibility and speed can greatly assist programming analysis that could produce metrics such as those that feed sustainability metrics.

It is beyond the scope of this report to describe in detail the operating of modern management systems or to describe the many types of iterative analysis they can produce. Very briefly, the management systems are based on the following key inputs:

- Inventories of assets
- Condition assessments of the assets
- Trend lines of past condition
- Deterioration rates for estimating future asset conditions
- Estimated traffic loadings
- Geographic referencing for mapping
- Costs per treatment type
- Complex optimization algorithms that recommend appropriate treatments based upon key inputs, such as available revenue
- Sophisticated communication modules that can produce maps, charts and reports that recommend investment scenarios and which report upon the infrastructure conditions that will result from such scenarios.

These kinds of outputs allow establishment of the needed investment that form the denominator of the sustainability ratios.

Despite the sophisticated computer analyses these systems produce, they still are reliant on the judgment of the agency subject matter experts for decisions on key parameters. One such parameter is how much pavement rehabilitation and replacement to realistically include in the "need" estimate. As noted in Chapter 1, thousands of lane miles of U.S. freeways have pavement structure more than 30 years old and which in many cases would warrant rehabilitation or replacement. Totaling them all in a need estimate would produce very large estimates that would dwarf credible estimates of available revenue. Engineering and economic judgment should temper the need estimate. Otherwise, the sustainability ratios are unlikely to withstand scrutiny from legislators and other policy makers.

Table 40 is the product from one State's bridge management system regarding the needed level of investment by treatment category for the State to sustain its bridge condition targets for the next decade. Such estimates greatly facilitate the generation of the sustainability ratios and are typical of the type of estimates the management systems can produce.

Table 40. *10 year bridge investment need.*

2012–2021 Estimated Bridge Needs	
Treatment Type	**Treatment Cost**
Preservation	$1,101,998,128.20
Rehabilitation	$491,352,834.35
Replacement	$2,324,800,926.00
Total	$3,918,151,888.55

Inventory-Based Estimates

Another way to estimate the needed levels of investment could be called an "inventory based method" because it relies upon applying deterioration curves to existing inventories of assets and using the results to predict needed treatments, and the treatments' costs.

Table 41 illustrates a simplified type of analysis for the sections of one route. Based upon the conditions, the appropriate treatments are assigned to the pavements. The pavement rated 85 is slated for preventive maintenance, the one at 55 is slated for selected full depth repairs and resurfacing while the one at 66 is scheduled for resurfacing. The pavement at 90 is not scheduled for any treatment in this year. The treatment costs are estimated from unit costs and the predicted pavement conditions after treatment are shown. From the pavement conditions, the remaining service life until next treatment is predicted. The prediction can be based on formal deterioration curves, engineering judgment or a combination of the two.

This type of analysis can occur manually for a small network or through a combination of automated and manual efforts for a larger network. Such an approach is used routinely by agencies that lack management systems. The approach works for smaller networks but lacks the ability to run scenarios and iterations that can be performed in the more sophisticated management systems.

Table 41. *Example of pavement need estimate.*

Pavement Sections	Length	Condition	Treatment	Cost/ Lane Mile	Project Cost	Projected Condition	Remaining Service Life (Years)
00.00–5.25	5.25	85	Preventive Maintenance	$45,000	$472,500	100	6
5.25–11.40	6.15	55	Resurfacing, 10% Full Depth Repairs	$100,000	$1,230,000	100	12
11.40–18.50	7.1	90	None	$0	$0	90	8
18.50–25.00	6.5	66	Resurfacing	$90,000	$1,170,000	100	12
Total	25				$2,872,500		

The inventory based method requires substantial manual effort to compile the network-wide information. It also lacks the sophisticated output systems to generate the standard reports that help to explain the scenarios. However, when such systems are supported by information technology staffs they have been used to produce meaningful asset management programs. While they have some disadvantages compared to the commercial management systems, they do provide transparency to the district personnel and others who can produce the inventory-based scenarios. Key inputs such as current conditions, estimated effect of treatments and estimates of remaining service life are clearly evident and not generated from "black box" analyses that are not widely understood.

The simple analysis in Table 41 relates to only two lane pavements. Expanding the analyses to include all bridge, multi-lane pavements and maintenance needs clearly requires substantial levels of effort. The level of effort they require explains the attractiveness of the formal computerized management systems and explains their expanded use in recent decades. As shown, however, in the Ohio case studies, some States have produced maintenance management processes by basing maintenance needs upon manually collected inventories of maintenance items. Such approaches could be replicated, particularly for smaller roadway networks.

Depreciation Method

A third way to calculate need would be through straight-line depreciation such as used for the GASB 34 financial reports. The GASB 34 Implementation Guide allows use of modified or composite deterioration methods in order to lessen the financial burden of reporting. Composite methods refer to depreciating groups of similar assets using the same deterioration rate. For instance, if bridges are determined to have a useful life of 50 years, each year one-fiftieth of the value of the bridge inventory is calculated as depreciation. The examples used in the GASB 34 Implementation Guide are provided primarily for determining asset valuation. They help determine the current year values of individual assets each of which was built over different years. However, the logic also can be used to determine annual needed levels of investment in the simplest scenarios for determining sustainability ratios.

In Table 42 below, the local government owns 10 bridges, each with the original bridge cost shown. Applying a 50 year service life to each structure results in annual depreciation of 2 percent. The amount of annual depreciation is shown for each structure and totaled as $271,000. Therefore under a simple straight-line scenario, the $271,000 provides the local government with an estimated

Table 42. *Bridge depreciation costs.*

	Estimated Useful Life	
Bridge Cost	50 Years (2% annually)	Annual Depreciation
$2,000,000		$40,000
$1,000,000		$20,000
$500,000		$10,000
$1,500,000		$30,000
$1,800,000		$36,000
$2,100,000		$42,000
$750,000		$15,000
$1,250,000		$25,000
$900,000		$18,000
$1,750,000		$35,000
Annual Total		$271,000

amount of preservation and maintenance it should budget in order to sustain its structures. Obviously, the amount of outlay would vary considerably year to year as specific maintenance treatments are required over an inventory of different bridges, each of a different age and condition and each experiencing different loadings. However, as a number to be used as a 10-year average expenditure, the $271,000 would be consistent with the GASB 34 guidance. It could be used by a local government to inform decision makers of the order-of-magnitude levels of bridge investments necessary to sustain the community's bridge network.

Table 43 from the *GASB 34 Implementation Guide* illustrates examples of estimated useful lives by asset class that could be used to calculate annualized depreciation rates. As the GASB 34 guidance notes, agencies are free to add additional categories of assets, and to subdivide them into more classes to provide more robust depreciation schedules.

Table 43. *Useful service life.*

	Estimated Useful Life
Component	
Bridges	50
Roadways	25
Curbs/gutters	15
Street lights	15
Traffic signals	18
Street signs	10

Although simple in concept, this type of straight-line depreciation is used in the annual financial reports of some major turnpikes to satisfy the GASB reporting and to satisfy bond holders. Although it lacks the sophistication and detail of the other types of analysis, it could be used as a beginning method to develop the needed levels of investment that would serve as numerators in sustainability metrics.

CHAPTER 10

Summary and Observations

This report examined the concept of a suite of proposed performance measures centered on an Asset Sustainability Index. The metrics are intended to be forward looking, predictive and comprehensive. They are intended to provide an important, bottom-line answer to a basic question—will highway assets be in better or worse condition in the future based upon the investments and programs of today?

The concept of sustainability metrics is not original having been used since at least 2009 in Australia. The Australia precedents reflect the growing interest in the financial sustainability of programs so they do not impose undue costs upon future users. The European debt crisis rocked international financial markets because of concerns that some European government expenditures were financially unsustainable. In the United States, concerns over the national debt and the long-term solvency of entitlement programs override all other policy debates. In the private sector, the long-term solvency of the mortgage bond market led to a financial downturn that reverberates throughout the economy.

All of these issues involve analysts concluding that the current path of spending and investment is unsustainable and creates long-term deficits that will be passed on to future generations. A growing perspective is that responsible governance includes an obligation to create sustainable programs that do not impose undue costs upon future taxpayers. As noted in a Queensland, Australia, sustainability act, *"A local government is **financially sustainable** if the local government is able to maintain its financial capital and infrastructure capital over the long term."*

To date, there have been few widely published metrics with which to illustrate whether a highway-infrastructure deficit looms, be it at the national, State, regional or local level. The GASB 34 reports provide some insight but they are not frequently read and they are backward-looking without future forecasts. The ASI is a mirror-image GASB. It looks forward to whether current investments will increase, or at least sustain, infrastructure conditions.

Transportation sustainability metrics could allow transportation professionals to illustrate whether the trajectory of infrastructure investment will be adequate to sustain critical highway conditions for the long term. In recent decades, national infrastructure condition trends have been positive. Bridge and pavement conditions on the National Highway System have improved significantly. However, the past performance guarantees little for the future. The past 5 years have seen highway agencies hit by rising prices, lower fuel tax receipts, deferred maintenance, and the steady aging of key assets such as the bridges and pavements built during the Interstate Highway era. Although some major highway metrics are trending positively, they are lagging metrics that provide only inference, and not certainty, about the future direction. Therefore, the gains of past years may not be a certainty for the future.

However, powerful modern asset management systems routinely produce scenarios of likely future conditions based upon expected levels of expenditures. These management systems allow transportation agencies to report whether current investment levels are adequate to offset the likely depreciation of asset values and deterioration of asset conditions. Such forecasts can allow new understanding of whether transportation agencies are incurring "infrastructure deficits" that will manifest in the future as lower conditions and substantially higher costs for future taxpayers.

As used in Australia, the sustainability metrics complement, not replace, existing metrics such as pavement roughness and bridge structural conditions. The sustainability metrics provide additional insight into whether long-term investment deficits are developing, the magnitude of those deficits and the long-term cost to close those deficits.

Future “infrastructure deficits” don’t typically show up on the balance sheets of transportation agencies so they have not received the same attention as have the deficits for the Federal budget, Medicare, Medicaid or Social Security. Although it doesn’t appear on balance sheets, underinvestment in infrastructure does create future financial obligations that are, in many cases, undocumented to the public.

Consolidating Key Performance Focus Areas

Sustainability measures complement four important focus areas of transportation policy—asset management, performance management, accountability and sustainability. Asset management is a proven strategy for rationally managing transportation assets for the lowest cost over their complex lifecycle. Performance management sets clear targets and measures progress toward those targets. Accountability often flows from both asset management and performance management because the two disciplines provide documentation of the agency’s focus and its accomplishments. Sustainability addresses whether the agency is meeting not only short-term needs but also leaves future users adequate resources to meet their needs. Asset sustainability metrics inherently incorporate all four areas of concern: asset management, performance, accountability and sustainability.

The transportation community has struggled to identify a handful of measures that accurately reflect the performance of the highway system overall. Using only a handful of metrics regarding current bridge and pavement conditions doesn’t provide much insight into whether long-term performance will be assured. As highway agency officials realize, the long-term performance of highway infrastructure is strongly influenced by long-term decisions. The performance of an asset is influenced by how it was designed, constructed, inspected, maintained, repaired, rehabilitated and eventually replaced. A typical highway agency juggles thousands of bridges and tens of thousands of lane miles of pavements, all of whose performance is influenced by various factors such as different traffic loadings, soil conditions, past condition, treatment histories, climate and hydrology. To intelligently manage such heterogeneous networks requires sophisticated asset management processes. These processes require accurate asset inventories, realistic deterioration curves, credible estimates of the effect of various treatments, and predictable asset service lives.

The Australian local government approach to this complex measurement problem has been through the sustainability metrics. Basically, agencies are required to developed credible, long-term asset management plans predicated upon sustaining infrastructure conditions at acceptable levels for the long-term, which is for 10 to 20 years. Those asset management plans must have credible financial plans that are also measured. The key performance metrics derive from the degree to which the asset management plan is financed and accomplished. Also included are many of the traditional metrics such as pavement smoothness, bridge adequacy and the condition of roadway features such as signs, guardrail and pavement markings. These traditional key performance indicators are retained but they are placed in a larger context of whether their targets are met not only in the short term but also for the long term. As a result of the long term focus, key asset management strategies such as preventive maintenance and timely rehabilitation become encouraged because of their contribution to long-term, cost-effective performance. When performance measures are focused only on short-term conditions and expenditures, the benefits of preventive maintenance or rehabilitation are not as strongly emphasized.

U.S. Precedents for Sustainability Metrics

The research effort for this report included reviewing selected U.S. asset management data to determine if U.S. agencies could produce such long-term indicators. The U.S. examples indicate that it is possible to “tease out” asset sustainability metrics from asset management systems commonly used in the United States. All the components of an asset sustainability analysis were found in the case study agencies. The NCDOT produces a Maintenance Condition and Assessment (MCAP) Report that included many elements of a sustainability index. UDOT’s advanced asset management practices allowed the calibration of investment levels for many asset classes with significant granularity down to the regional level. MnDOT produces a report that could support an ASI by calculating the long-term need for bridge and pavement inventories. The ODOT example illustrated how the department for more than a decade has been calibrating investment levels to keep asset conditions meeting the established target, both for the current program and for up to 10 years in the future.

The U.S. case studies appear to indicate that sustainability metrics are possible with current U.S. asset management practice. They also indicate that the examples provide substantial insight into the trend lines of conditions and the likely expenditure levels that will be required. The precision of the four case study agencies' asset management processes demonstrate that investment could be calibrated to achieve precisely defined condition levels.

Uses of the Sustainability Metrics

Although the index and ratios are considered to be simple in concept, the ASI can be an informative metric useful for long-range plans, short-term State Transportation Improvement Programs or for public budgeting decisions particularly when tracked over time. They boil down complex, long-term infrastructure condition and investment analysis into a suite of easy-to-illustrate metrics. The insight they provide increases with the length of the analysis period.

As described in Chapter 7, the ASI is a composite of indices for bridges, pavements and roadway maintenance items. As a composite, it provides one at-a-glance summation of a large amount of asset management and fiscal information. Also, as a composite, it allows the information within it to be disaggregated for detailed understanding of the adequacy of investment by asset class, or by region.

The ASI is generated, in effect, when a credible Transportation Asset Management Plan is developed coupled with a credible financial plan. The amount spent becomes the numerator and the needed level of investment is the denominator to compute the ASI. Because the TAM Plan includes sufficient detail by asset class, it allows analysis as to adequacy of investment in the various classes of assets.

Tables such as Table 44 illustrate the type of program-level information that can be disaggregated from an ASI. Each program has its own Sustainability Ratio which rolls up into the overall ASI. In this theoretical case, over 10 years the adequacy of overall investment falls from a ratio of

Table 44. *Example of how sustainability indices can illustrate program needs.*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pavements	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.77	0.76
Major Routes	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.74	0.73
Arterials	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Collectors	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Pavement Rehabilitation/Replacement	0.40	0.40	0.39	0.39	0.38	0.38	0.38	0.37	0.37	0.37
Pavement Preventive Mainenance	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Bridges	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82
Preventive Maintenance/Preservation	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82
Sub and Superstructures	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79
Decks	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82
Painting	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Maintenance	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Guardrail	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Pavement Markings	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Drainage	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Signage	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Vegetation/Roadside	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Pavement Surfaces	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Overall ASI	0.88	0.87	0.855	0.84	0.83	0.82	0.81	0.79	0.77	0.75

.88 down to .75. The degree of underfunding by asset class is apparent, allowing policy makers to set priorities as they make incremental funding decisions.

A table such as Table 44 could add significant insight into a TAM Plan, a STIP, a long-range plan or to agency budget testimony.

Austroads is the association of transportation agencies in Australia and New Zealand. It developed a set of recommended asset sustainability metrics that agencies can use to demonstrate accountability to stakeholders. Austroads notes that "sustainability" has evolved a new meaning in recent years to embrace environmental, social and economic prosperity, or a Triple Bottom Line. The 20-year focus of both asset management plans and infrastructure financial plans is intended to ensure that public agencies today do not consume the benefits necessary to sustain future generations. These benefits extend to the economic benefits or economic value of highway infrastructure. In effect, investing adequately today to protect the needs of future users is the essence of infrastructure sustainability, according to Austroads.

"If the Agency's long-term finances are sustainable, then disruptive tax increases or spending cuts can be avoided, the taxation burden will be fairly shared between current and future taxpayers and the stability or predictability of government taxes and charges will not be at risk," the guidelines notes.[10]

Complementary Asset Valuation

The examination of Australian and British practices illustrates how the sustainability indices are enhanced further when complemented with "asset valuation" information. "Growing community equity" is viewed as a government responsibility in the Australian and British asset-management frameworks. By tracking over the long-term whether a transportation agency's assets are increasing or declining in value, the effect of investment can be displayed. If asset values decline, society is losing its highway equity and not replenishing that equity for future users. In Australia, Great Britain and in the private sector, Asset Valuation serves as a complementary metric to those such as the ASI. They seek to determine whether current actions increase or decrease "public equity."

British valuation guidance for local governments emphasizes that asset valuation is about accountability and transparency in support of sound infrastructure policy. It says in part: "A fundamental component of long term planning is to ensure the asset base is preserved and replenished in a sustainable way without imposing an undue financial burden on future generations. The preservation of the asset base can be measured and monitored over time using a robust asset valuation procedure that provides a true and fair value of the assets."[11]

The guidance notes that the mere assigning of monetary value to highway assets casts them as an important public asset worthy of preservation. The long-term reporting of the value of the public's assets is an important mechanism for demonstrating stewardship. Monitoring how the value of highway infrastructure is rising or falling indicates if costs are being unduly passed on to future generations. It also provides compelling arguments for sound asset management and sufficient investment. As such, the asset valuation process can produce important metrics that support Performance Management and other forms of public accountability.

British guidance defines asset valuation as the calculation in terms of monetary value of a government's physical assets. It allows the estimating of the "consumption" of a society's physical assets over time and compares that consumption with the renewal and replacement of assets. It notes that the main drivers for asset valuation are:

- To emphasize the need to preserve the highway infrastructure by placing a monetary value on highway infrastructure assets;
- To demonstrate asset stewardship by monitoring the asset value over time;
- To promote greater accountability, transparency and improved stewardship of public finances;
- To support highway asset management.

By reporting upon changes in asset valuation, overall depreciation and the improvement or impairment of assets over time, the agency can discern if its maintenance practices and investment levels are sufficient to sustain the assets at targeted levels. Analyzing the reasons for assets' decline can lead to improved maintenance practices, improved asset treatments or improved investment levels.

"These programs of work influence the asset value, i.e. the work program may maintain or increase the asset value or, if it is not adequate, then the asset value may decrease. Monitoring asset value over time can, therefore, be used to demonstrate stewardship of assets. This information provides an important input to a business case for investing in the maintenance and upkeep of public assets."[12]

Private Sector Precedents

Adequately investing in an organization's physical assets to ensure its long-term viability has long precedence in capital-intensive private sector organizations such as railroads, manufacturers and utilities. Many of these companies are required to publish annual reports to shareholders that include, among other metrics, the degree to which the companies are preserving their physical assets. In 2009, famous investor Warren Buffet of the Berkshire Hathaway holding company made the largest single investment ever for the company when he purchased the outstanding shares of BNSF railroad for $34 billion. In his annual letter to shareholders in 2010, Buffet noted that BNSF will remain profitable and attractive if Berkshire Hathaway continues the substantial infrastructure investment in BNSF that has made the company successful in recent decades. He referred to the "social compact" Berkshire Hathaway has with society to continue sustaining the infrastructure of this important railroad, and other holdings such as its utility companies.

"All of this adds up to a huge responsibility," he wrote in his shareholders letter. "We are a major and essential part of the American economy's circulatory system, obliged to constantly maintain and improve our 23,000 miles of track along with its ancillary bridges, tunnels, engines and cars. In carrying out this job, we must anticipate society's needs, not merely react to them. Fulfilling our societal obligation, we will regularly spend far more than our depreciation, with this excess amounting to $2 billion in 2011. I'm confident we will earn appropriate returns on our huge incremental investments. Wise regulation and wise investment are two sides of the same coin."

Observations

This report concludes by making these observations.

First, the continuing development of asset sustainability metrics in Australia will provide additional lessons as to the value and challenges of these indicators. Australian practice is relatively new, with the State asset sustainability statutes having gone into effect in 2009. As the Australian State of practice matures among dozens of local governments, many best practices may be found. Particularly important will be Australian efforts to standardize and improve the development of asset management plans. These plans can serve as the standard template for generating the needed level of investment that could sustain the highway networks for a long-term horizon.

Secondly, the U.S. research and asset management community can provide important assistance by illustrating how the modern asset management systems can produce informative long-term forecasts for policy makers. It is clear from the examples in this report that many highway agencies already produce such long-term forecasts that illustrate the future consequences of today's transportation programs. These State practitioners lack the benefit of a common forum in which they can exchange examples, provide peer support and develop common research agendas. Focusing research efforts and conference presentations on best practice in sustainability metrics can advance the developing State of practice.

Third, U.S. asset management practitioners can consider adding the concept of long-term sustainability to the issues they include in major planning documents such as long-range plans and State Transportation Improvement Programs. Sustainability is a concept and framework that has taken root in policy circles. As the U.S. grapples with deficits in major programs such as Social Security or Medicaid, the concept of looking long-term at how to sustain these programs consumes increasing public attention. The momentum that the concept of sustainability has gained can serve as a slipstream into which discussion about U.S. transportation needs can enter. Intuitively, the public understands that aging pavements and bridges eventually will need replacement. The sustainability metrics and the sustainability concept can help to further clarify public understanding. The metrics demonstrate that U.S. transportation officials are able to forecast long term and they can calibrate the degree of investment the U.S. should make to leave a sustainable transportation system for future users. The use of sustainability metrics allow transportation agencies to demonstrate they are accountable not only to today's taxpayers and transportation users but also to tomorrow's.

ENDNOTES

1. Queensland Department of Local Government and Planning, Financial Management (Sustainability) Guideline, 2011, pg. 20.

2. Queensland Department of Local Government.

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4. Austroads, "Guide to Asset Management Park 8: Asset Valuation and Audit", pg. 2.

5. County Surveyors Society/TAG Asset Management Working Group", 2005 Edition, pg. 4.

6. Ohio Department of Transportation, *"Asset Management Peer Exchange,"* document, Sept. 7, 2004, at a TRB workshop.

7. Minnesota DOT, *"Highway Investment Plan Annual Update 2011-2020"* Table 1, pg. ii.

8. Government Accounting Standards Board, 1999, *"Summary of Statement No. 34 Basic Financial Statements—and Management's Discussion and Analysis—for State and Local Governments"* accessed at http://www.gasb.org/st/summary/gstsm34.html accessed l 6, 2011.

9. Chait, Edward P. *"Report 608 GASB Methods for Condition Assessment and Preservation",* National Cooperation Highway Research Program, pg. 1.

10. Austroads, "Guide to Asset Management Park 8: Asset Valuation and Audit", pg. 2.

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