

3.0 Future Performance and Investment Framework

Vermont’s highway network serves the vast majority of all freight and passenger travel in the State, and is of critical importance to the State’s economy. The system requires continuing investments to maintain its function and continue to serve the transportation needs of residents, employees, industries and visitors. The list of maintenance and improvement needs is large; including pavement resurfacing; replacement or rehabilitation of older bridges; expansion of capacity to relieve congestion in the urbanized portions of the State; roadway improvements to enhance traffic flow; measures to improve safety for motorists, bicyclists and pedestrians; traffic calming treatments, and so on. Inevitably, the dollars available for investment in the highway system fall short of the level that is desirable.

Investment choices should be made based on a detailed understanding of the specific needs and opportunities at different locations, but also with a higher-level view of the implications of different investment levels on different portions of the system. This section presents a high-level framework that facilitates a “bird’s-eye” view of current and future highway system performance under different investment scenarios. This kind of view can provide valuable guidance for overall resource allocation, which complements the existing well-defined “bottom-up” methods for project identification, scoping, and design.

The performance and investment framework includes three key elements:

- Performance categories and goals, defining the major considerations driving the identification and evaluation of highway investments (Section 3.1);
- Definition of different highway system subnetworks for which different performance targets or approaches to improving performance may be appropriate (Section 3.2); and
- Specific performance measures and targets pertaining to the different subnetworks that address the performance goals (Section 3.3).

The section concludes with a 10-year analysis of future investment levels versus predicted performance for pavements and bridges, which account for the lion’s share of the highway investment needs.

■ 3.1 Performance Categories and Goals

This section describes a set of broad performance categories that provide an organizing framework for selecting appropriate performance measures for the highway system, and identifies goals for each performance category. The performance categories are:

- **Preservation** - Maintaining the physical integrity and intended function of the existing system;
- **Safety** - Preventing crashes, injuries and fatalities on the highway system;
- **Mobility** - Improving travel convenience and reducing travel time for passengers and goods movement; and
- **Environment/Quality of Life** - Protecting natural resources and historic sites, and maintaining Vermont's scenic beauty and quality of life.

These categories are intended to clearly and simply communicate desired outcomes for investments in the highway system. The categories recognize the goals established in the LRTP and subsequent objectives established by the agency's Secretary and Executive Staff as well as work completed to date by VTrans on establishing internal performance measures for the agency's budget process. The categories also relate to the highway program structure, i.e., the categories used for organizing projects or allocating funding. This allows the desired outcomes from highway investments to be directly related to the planned expenditures in each program category, and also helps to establish clear evaluation criteria for particular types of projects.

Transportation goals for each category are shown in Table 3.1. These goals are consistent with the LRTP and other existing VTrans policies such as the Safety Management System, and also reflect feedback from agency staff and other stakeholders in the development of the Highway System Policy Plan.

These goals guide the identification of specific performance measures and targets for every category and goal. Each of the goals also is considered in the development of highway policies and strategies, as discussed in Section 4.0.

Table 3.1 Performance Categories and Goals

Performance Category	Goals
Preservation	<ul style="list-style-type: none"> • Protect the existing investment in the highway network by keeping it in serviceable condition. • Provide acceptably smooth and safe driving surfaces. • Minimize the need to restrict or close bridges by maintaining their structural integrity in accordance with current and anticipated loadings. • Negate the risks of structure failure. • Minimize the life-cycle cost of maintaining acceptable condition levels.
Safety	<ul style="list-style-type: none"> • Minimize the occurrence and severity of crashes on the highway network through application of appropriate, context sensitive design standards and cost-effective improvements to address high-accident or high-risk locations. • Minimize conflicts between vehicles, pedestrians and bicycles.
Mobility	<ul style="list-style-type: none"> • Maintain safe and efficient flow of traffic at acceptable speeds. • Provide convenient interstate and intercity connections for passengers and freight. • Support economic development consistent with established regional and local growth plans. • Provide convenient connections to intermodal facilities.
Environment/ Quality of Life	<ul style="list-style-type: none"> • Support and reinforce state policies for compact growth patterns. • Manage undesirable impacts of truck traffic in downtown areas. • Minimize negative environmental impacts of highways. • Maintain existing air quality attainment status.

■ 3.2 Highway System Elements

Given the performance categories and goals for the highway system described above, the next step in the development of the Highway System Policy Plan was to identify how policies for achieving these goals, and performance measures for tracking their achievement should vary across different elements of the highway system.

For Preservation, it is useful to define different portions of the highway system based on overall function and level of importance. While it is desirable for all roads and bridges to be maintained in good condition with proper preventive maintenance, resource limitations inevitably force difficult choices. In making such choices, it is common to distinguish higher-priority components of the highway network, which tend to be more heavily

traveled and/or form part of a backbone network of statewide significance, from components that are more lightly traveled and serve trips that are more local or regional in nature. Once different segments of the highway network are defined, the condition, remaining life or remaining value of infrastructure can be monitored for these different segments, and preservation resource allocation decisions can reflect the relative “health” of these different segments.

For Safety, policies and performance measures are most appropriately set on a system-wide basis – the objective is to prevent and reduce crashes, injuries and fatalities on the entire highway system in the most cost-effective manner – thus no specific highway system elements have been defined for purposes of differentiating safety-related policies.

For Mobility, it is most logical to examine system performance and establish policies at a corridor level, where corridors are defined as one or more routes connecting major origins and destinations. A corridor perspective allows for tracking of “how long does it take to get from A to B?” It also allows for policies to vary based on the presence of alternate routes and/or modes.

For both Mobility and Quality of Life goals, it is also important to consider current and planned/desired land use characteristics adjacent to the highway. The nature of adjacent land use affects both performance objectives and policies in the following ways:

- Highway users tolerate greater levels of congestion in urban areas than in rural settings – congestion-related performance targets often reflect this distinction;¹
- Land use characteristics determine constraints on the nature of improvements that should be considered based on concerns for historic preservation, environmental sensitivity, noise and traffic disruption; and
- Access and corridor management policies need to reflect the nature of existing land uses, and account for both designated growth areas as well as areas at high risk for emerging development patterns that could adversely impact future highway operations.

Therefore, three types of overlay categories are defined for establishing highway system performance standards and policies – one based on subdivisions of the network, one based on intercity corridors within the State, and one based on land uses. Each of these categories is discussed below.

¹ The AASHTO Green Book (*A Policy on Geometric Design of Highways and Streets 2000*, 4th Edition, American Association of State Highway and Transportation Officials, Washington DC), pp. 76-85 includes a discussion of criteria influencing driver perception of congestion, as well as recommendations for higher levels of service on rural than urban facilities.

Networks

This policy plan designates a Primary Network for establishing preservation standards and certain design and investment policies (see Figure 3.1). The proposed Primary Network coincides with the existing Vermont commercial vehicle network shown in Figure 2.9. The term “Primary Network” was chosen to reflect the broader function of this network as providing not just an essential set of links for statewide goods movement, but also for statewide passenger movement connecting the primary population centers. The Primary Network includes the NHS and designated NHS Intermodal Connectors as well as portions of other routes (including VT 22A, U.S. 302, VT 105, and urban avoidance routes), which have been designated by the State as important for interregional travel, and connect the larger population centers in Vermont. As illustrated in Figure 2.13, 76 percent of the State’s population and 86 percent of its employment are within a 10-minute drive from the Primary Network. The Primary Network (including the Interstate System) carries 60 percent of the vehicle miles of travel (VMT) on the SHS.

The *Interstate System* is called out as a subcategory of the Primary Network, given its particular importance to the highway transportation system in Vermont, and the nation. The Interstate system accounts for one-half of the Primary Network mileage and also carries half of the Primary Network vehicle miles of travel (or 30 percent of SHS VMT)².

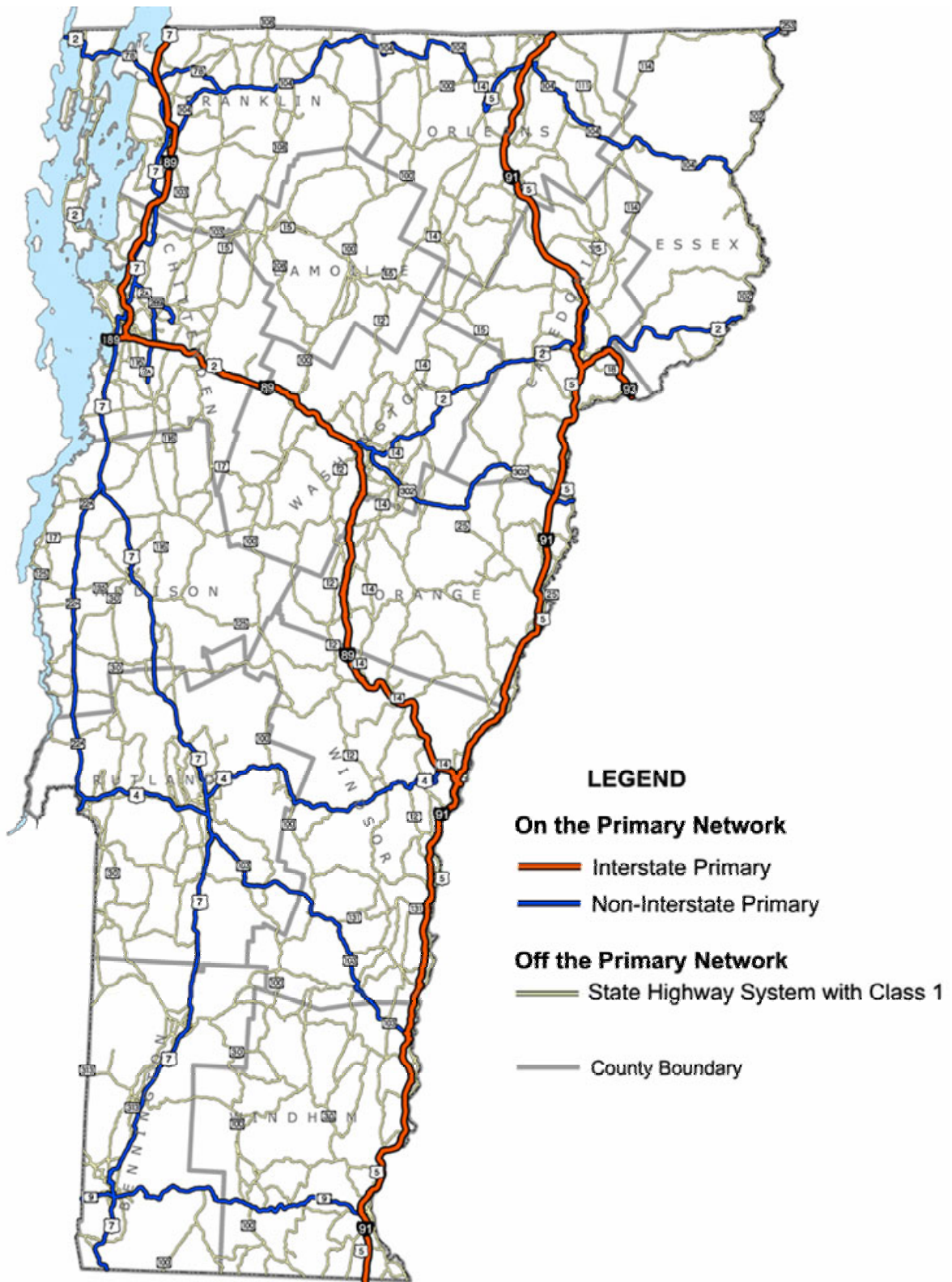
The SHS represents the entire set of highways that are under VTrans jurisdiction. Class 1 town highways, which are extensions of state highways through towns, represent an important complement to this system, even if they are not directly under VTrans jurisdiction, because they create a continuous system of routes that are used for intrastate travel. The portion of the SHS off of the Primary Network accounts for over one-half of the total SHS mileage, and carries roughly 40 percent of the SHS vehicle miles of travel.

For performance standards in this policy plan that vary by network level, three highway subnetworks are used, reflecting the above definitions:

1. The Interstate Highway System (“Interstate”);
2. Other roads on the Primary Network (“Non-Interstate Primary”); and
3. Other roads on the SHS (“Off-Primary”).

² This statistic is from the pavement management system, which tracks two-lane miles rather than centerline miles. Two sides of a divided highway are treated as separate sections. Therefore, the Interstate mileage from the pavement management system is roughly double the number of Interstate centerline miles (as reported in Table 2.1).

Figure 3.1 Vermont Primary Network



Corridors

Assessing the performance of the highway system with respect to mobility is best done using a corridor approach; for example, by measuring travel time along routes that serve as major intrastate or interstate travel corridors. This policy plan defines a set of intercity corridors that consist of pairs of primary population centers, connected by the Primary Network. These corridors are shown in Table 3.2.

The corridors represent major origin-destination pairs (including connections to neighboring states). A few corridors have been defined with an origin or destination within New York State in order to reflect actual trip-making characteristics. However, performance targets for corridors apply only to the portion of the corridor within the State of Vermont.

Table 3.2 Major Intercity Corridors

Start	End	Route
North-South		
Bennington	Rutland	U.S. 7
Rutland	Burlington	U.S. 7
Albany, New York	Burlington	I-87/U.S. 4/VT 22A/U.S. 7
Burlington	Canadian Border	I-89
Burlington	Champlain, New York	I-89/VT 78/U.S. 2
Burlington	Montpelier	I-89
Montpelier	White River Junction	I-89
Brattleboro	White River Junction	I-91
White River Junction	Canadian Border	I-91
East-West		
Brattleboro	Bennington	VT 9
Brattleboro	Rutland	I-91/VT 103
White River Junction	Rutland	U.S. 4
Rutland	New York State Line (Fair Haven)	U.S. 4
Montpelier	St. Johnsbury	U.S. 2
St. Johnsbury	New Hampshire Border	I-93
Burlington	Newport	I-89/VT 105, or VT 15/100

Land Use

Land use area types are the third category for establishing performance targets and highway policies. The land use categories follow the basic structure defined in the Vermont State Design Standards, which allow for variation in roadway cross sections and levels of service based (in part) on land use category. Thus, the recommended land use categories are:

- **Large Cities and Towns.** These are downtown commercial districts within urban areas. Performance standards recognize that a higher degree of congestion is tolerated in urban areas; policies for these areas recognize the need to balance mobility with local access provisions.
- **Smaller Towns and Villages.** These include smaller downtown areas and traditional village centers that are not urban in character. Performance standards and policies for these areas recognize the smaller scale of activity as well as the desire to preserve the historic character of these centers.
- **Suburban Corridors.** These are corridors outside of downtown areas, but within or adjacent to urban areas where lower-density commercial and residential development has occurred.
- **Rural Corridors.** These are defined as highway sections outside of urban areas where adjacent land is undeveloped. Performance standards and policies for these areas facilitate the movements of primarily through traffic.

An additional overlay on the land use categories acknowledges locally designated growth centers. These may coincide with existing towns and villages, or may be new planned areas. Proactive planning to maintain capacity and service on highways serving designated growth areas is an important aspect of the Highway System Policy Plan.

The growth center concept has been developed over the past 15 years by state and local agencies, organizations, and community groups. The idea is that certain areas should be designated for future growth, in a manner that allows supporting infrastructure to be planned for and efficiently provided. Land outside of these areas will remain largely rural in character. The Agency of Natural Resources (ANR) defines growth centers as areas for concentrating development, consisting of “moderate to high-density development, a range of housing options with nearby shopping and employment opportunities, and pedestrian, bicycle and transit accessibility.”³ ANR is using the growth center concept in establishing wastewater improvement funding priorities.

³ Agency of Natural Resources, “Infrastructure Funding Programs and Growth Centers White Paper.” Draft 9, May 9, 2001. <http://www.central-vt.com/legis/growctr/anrgrow.htm>.

Characteristics of growth centers that are particularly relevant to transportation include:

- Lot size, road width, and setback requirements that replicate traditional growth center patterns already present within historic communities; and
- A circulation system that is conducive to non-motorized travel, and supports transit opportunities.

■ 3.3 Performance Measures and Targets

Selected performance measures and targets for different highway system elements are discussed below by performance category (preservation, safety, mobility, and environment/quality of life) and are summarized in Table 3.3. These measures and targets were chosen based on reviews of other state practices, as well as on discussions with VTrans staff regarding which measures and targets would be most appropriate and feasible to establish for the Vermont SHS. The performance measures in this plan are designed to represent the customer’s perspective, and therefore are organized by category, since these categories directly relate to how the system is perceived by the user.

Table 3.3 Vermont Performance Measures and Targets

Performance Category	Performance Measure	Level of Application	Baseline (2002)	Target
Preservation				
Pavements	Average Condition Index of Vehicle Miles Traveled	Interstate	79	Maintain existing conditions ¹
		Non-Interstate Primary	68	
		Off-Primary	62	
	Percent lane miles with “very poor” condition rating	Interstate	1%	Maintain existing conditions ¹
		Non-Interstate Primary	7%	
		Off-Primary	23%	
Structures	Number of restricted bridges (weight limits, height restrictions, one-lane bridges)	Interstate	0	0
		Non-Interstate Primary	2	Maintain adequate connectivity; keep bridges open or provide detour route
		State-owned Off-Primary	6	
	Number of structurally deficient bridges (>20 feet)	Interstate	36	Maintain existing conditions ¹
		Non-Interstate Primary	27	
		State-owned Off-Primary	116	
	Number of structurally deficient short structures (six to 20 feet)	Interstate	48	Maintain existing conditions ¹
		Non-Interstate Primary	50	
		State-owned Off-Primary	129	
	Average health index (> 20 feet)	Interstate	90	Maintain existing conditions ¹
		Non-Interstate Primary	88	
		State-owned Off-Primary	84	

Table 3.3 Vermont Performance Measures and Targets (continued)

Performance Category	Performance Measure	Level of Application	Baseline (2002)	Target
Safety				
	Number of major crashes per year ²	All	1,244 (in 1998)	Five percent reduction from 1998 to 2008 (per Safety Management System)
	Percent of high-priority safety needs addressed (high accident location and high benefit/cost improvement)	All		100 percent within five years of identification
Mobility				
	Average travel time between major cities	Corridors on Primary Network	See Table 3.4	No decline in average travel time from current levels
	Maximum V/C ratio on state highways	Urban area downtowns		0.9
		Rural corridors		0.7
		Other (small towns/villages, suburban corridors, growth areas)		0.8
	Percent of employment within 10 minutes of the Primary Network	All	86% (2000)	Maintain current level
	Percent of Employees Living within 10 minutes of the Primary Network	All	76% (2000)	Maintain current level
Environment/Quality of Life				
	Air quality attainment status	All	No non-attainment areas	Maintain current attainment status

¹ Pavement and bridge preservation targets to “maintain existing conditions” refer to the overall system condition and not to individual projects. These targets should be viewed as “pragmatic” given current fiscal realities. Desirable targets for preservation are discussed below.

² Major crashes include fatal, “serious injury,” and “moderate injury” crashes.

Preservation

Pavements. The two selected pavement performance measures are consistent with those which have been used by VTrans over the past several years. Both measures are customer-oriented; i.e., they are proxies for the impacts of pavement condition on road users. The first measure – average travel-weighted condition provides a broad picture of how pavement conditions experienced by road users are changing over time. This measure reflects that fact that responsible stewardship of the highway system requires not only fixing roads in very bad condition today, but also making prudent investments to prevent worsening conditions over the long term. Because it is generally more cost-effective to invest in a pavement still in fairly good condition than it is to replace a pavement in poor condition, it is important to carefully track the distribution of system length in different

condition categories or remaining life categories (e.g., zero to five years, five to 10 years, over 10 years), and make investments to minimize the overall life-cycle costs of maintaining pavements. VTrans uses a pavement management system which incorporates appropriate decision rules for what types of treatments are most cost-effective at different phases of a pavement's life. This tool should be used to track remaining life and develop replacement and rehabilitation cycles that minimize life-cycle preservation cost. The second measure – “percent in very poor condition” was selected as a supplementary measure to recognize the fact that road user costs (travel time, fuel usage, vehicle wear-and-tear, accidents) begin to increase significantly when pavement surfaces are very rough⁴.

Structures. The performance measures selected by the VTrans Performance Measures Subcommittee related to structures – number of restricted bridges and number of structurally deficient bridges – also are adopted in the Highway System Policy Plan. Separate targets are established for the Interstate system, the Non-Interstate Primary Network, and for state-owned bridges off of the Primary Network.

A *restricted* bridge is one which is either closed to traffic, or posted for reduced loads. A bridge is classified as *structurally deficient* if it has a poor condition rating for one of its major components⁵. In addition, the average *health index* is established as a performance measure. The health index is calculated by the VTrans bridge management system, and reflects the remaining value of bridges, accounting for the condition of each structure element, and their replacement (or failure) costs. This measure is analogous to remaining life, in that it can be set to move towards a preservation strategy that minimizes long-term preservation costs.

Desirable Preservation Targets

The “maintain existing conditions” target for pavement and bridges under the preservation performance category refers to the overall condition of the system and it does not address the condition of specific bridges or sections of pavement. This target was selected taking into account fiscal realities in the State and it represents a pragmatic rather than a desirable target. The *desirable* pavement and bridge performance targets are:

⁴ FHWA's Interim Technical Bulletin on Pavement Life-Cycle Cost Analysis (Publication FHWA-SA-98-079 – “Life-Cycle Cost Analysis in Pavement Design) cites research from New Zealand indicating that user costs begin to accrue at an IRI of 170 inches/mile, which corresponds to a Present Serviceability Rating (PSR) of 2.5 (fair condition) and increase non-linearly as condition declines.

⁵ Structural deficiency is determined based on National Bridge Inventory inspection results. A bridge is designated as structurally deficient if at least one of the following conditions are met: the deck, superstructure, or substructure is given a condition rating of 4 or below (poor) on a scale of 1-7; a culvert is given a condition rating of 4 (poor) on the 1-7 scale; the structure appraisal rating is 2 or below on a scale of 1-9 (intolerable, high priority for replacement); or the structure spans a waterway and its waterway adequacy is 2 or below on a 1-9 scale (intolerable with a high priority for replacement).

- **Both Pavements and Bridges** – maintain a distribution of condition that is sustainable over the long term with a relatively steady investment level and which minimizes life-cycle costs.
- **Pavements** – Keep the percent of very poor length to less than five percent on the Primary Network, and to less than 10 percent on the Off-Primary Network.
- **Bridges** – Eliminate all structurally deficient long structures on the Primary Network. Reduce the number of structurally deficient long structures off of the Primary Network to five percent or less of the total (no more than 26 of the 530 structures). Reduce the number of structurally deficient short structures on all networks below five percent of the total (no more than 65 of the 1,306 structures).

Safety

Work already performed for VTTrans to develop a Safety Management System (SMS) has established statewide goals for major or “serious” crash reduction of five percent by 2008. A serious crash is one involving a fatality, a serious injury or a moderate injury. The SMS recommended the use of serious crashes as the primary performance measure because these types of crashes have the highest economic and social costs. Supporting data are also more reliable for serious crashes, since minor crashes tend to be underreported.

The safety target established by the SMS is adopted by the Highway System Policy Plan, but is supplemented with an additional target that is related to the contribution to crash reduction attributable to highway safety improvements (as opposed to education, enforcement, and regulatory actions). This target is the percent of high-priority safety needs addressed, where “high-priority safety needs” are defined as consisting of an identified high accident or high-risk location with a high benefit/cost ratio for improvement. The Highway Safety Improvement Program (HSIP) identifies high-risk locations, provides a benefit/cost assessment of improvements, and includes a well-defined process for prioritizing and implementing safety improvements. The information emerging from the HSIP therefore provides a solid basis for establishing and tracking achievement of safety-related performance targets.

The social and economic costs of a crash are irrespective of the type of facility on which the crash occurs, and therefore safety performance measures are independent of highway classification.

Mobility

Mobility standards relate to the travel time and convenience with which people and goods can travel. Four basic mobility standards are defined in this policy plan:

- **Corridor travel time for major intercity corridors within Vermont.** Corridor travel time is an all-encompassing measure that reflects design speeds, levels of congestion, and directness of routing. Current corridor travel times and average travel speeds for major intercity pairs on the Primary Network were determined using the Statewide

Travel Demand Model – which estimates average daily traffic – and are shown in Table 3.4. There is no “absolute” standard for corridor mobility, and reasonably attainable travel times will depend on terrain, level of development, and other factors. Primary corridors with low average travel speeds compared to other corridors, though, are obvious candidates for improvement.

- **Volume-to-capacity (V/C) ratio.** V/C ratios relate to levels of congestion and delay on specific roadway segments. As the V/C ratio approaches 1.0, the roadway is operating at or near capacity, traffic flow conditions become unstable and delay increases significantly. This policy plan sets performance standards based on average daily traffic that vary by area type, with the most stringent standards in rural areas ($V/C < 0.7$) and the least stringent standards in urban area downtowns ($V/C < 0.9$). It is common to tolerate greater congestion levels for urbanized areas, especially densely built-up areas. Some level of congestion is inevitable in such areas, and congestion is generally more acceptable on a short-local trip than on a long-distance intercity trip. Also, the designs required to reduce or eliminate congestion may be incompatible with other fundamental qualities of the urban environment (e.g., density of population, pedestrian-oriented character, and historic character).
- **Percent of employment within 10 minutes of the primary network.** This is a measure of the extent to which the defined Primary Network adequately serves businesses in Vermont, for freight/goods access as well as access by workers and customers.
- **Percent of employees living within 10 minutes of the primary network.** This measure addresses the extent to which the primary network provides accessibility to Vermont employees living in population centers that are far away from employment centers.

These two measures of accessibility are affected not only by the location and extent of the Primary Network, but also by land use and development patterns. Over the long-term, the public cost of achieving performance targets for these measures will be lowered by regional and local land-use strategies that encourage development within designated growth centers currently well-served by the Primary Network.

In addition to the above four mobility measures, there are other factors that should be considered in making investments to improve mobility. Adequate data are not available, however, to set specific, quantitative standards for these measures. Some of these factors include:

- **Travel time reliability.** The ability to reach a destination within a known travel time is important, even if congestion is encountered during the journey. Crashes, work zones, and major events are three factors that can negatively affect travel time reliability.
- **Intermodal access and mobility for freight and passenger travel.** Providing adequate access from major freight generators or intermodal terminals to the NHS is an important concern for businesses. Load restrictions, permit requirements, and delays on truck routes also affect freight mobility. Passenger access to airports and rail and bus

terminals can be important for economic development as well as basic mobility purposes.

Table 3.4 Major Intercity Corridors: Baseline Mobility Levels⁶

Start	End	Travel Dist (Miles)	Travel Time (Minutes)	Speed (MPH)	Comments
North-South					
Bennington	Rutland	55	68	49	
Rutland	Burlington	67	96	42	via U.S. 7
U.S. 4 @ New York Border (from Albany, New York)	Burlington	65	89	43	via VT 22A
Burlington	I-89 at Canadian Border	43	44	59	
Burlington	U.S. 2 at New York Border (from Champlain, New York)	54	61	53	
Burlington	Montpelier	40	41	58	
Montpelier	White River Junction	56	56	60	
Brattleboro	White River Junction	62	63	59	
White River Junction	I-91 at Canadian Border	108	102	63	
East-West					
Brattleboro	Bennington	40	54	45	
Brattleboro	Rutland	73	90	48	via I-91/VT 103
White River Junction	Rutland	47	65	43	
Rutland	U.S. 4 at New York Border	19	25	46	
Montpelier	St. Johnsbury	37	51	43	
St. Johnsbury	New Hampshire Border	11	14	46	via I-93
Burlington	Newport	88	120	44	via I-89/VT 105

Note: Travel speeds reflect access and egress to/from town centers, so they are lower than mainline speeds.

Environment/Quality of Life

Environmental and quality-of-life concerns relate generally to the impacts of roads and vehicular traffic on noise, air quality, ecology, historic and scenic areas, and local communities. The impacts of heavy vehicle traffic, including noise and emissions, in densely

⁶ All travel distances and times are measured from the downtown of the respective city using Vermont’s Statewide Travel Demand Model.

settled town centers has long been a particular concern in Vermont. Broader concerns about sprawl also have been actively discussed – some Vermonters feel that highway policy should seek to prevent sprawl and encourage compact development patterns. However, the recent LRTP effort found that opinions about using transportation as a mechanism to limit urban sprawl are highly polarized.

Goals are commonly set in other states to achieve or remain in attainment with national ambient air quality standards. Currently, no areas in Vermont are in violation of air quality standards. However, the Burlington and Bennington areas may be at risk under the new eight-hour standards for ozone and particulate matter. This policy plan establishes a goal of keeping these areas in attainment.

As stated above, the mobility-related performance measure of maintaining the current proportion of employment within 10 minutes of the Primary Network reflects the Environmental goal of supporting compact development patterns.

The HSPP does not establish explicit quantitative performance measures for the remaining two goals in the Environment/Quality of Life category (manage undesirable impacts of truck traffic in downtown areas, and minimize negative environmental impacts of highways). These goals are best addressed in the context of particular locations, and there are existing environmental regulations and project development processes in place to determine appropriate standards and strategies that fit specific circumstances.

■ 3.4 Investment Tradeoffs

Advances in data analysis and modeling techniques are providing tools that can be used to assess tradeoffs resulting from different levels of investment. Two VTrans asset management systems include the capability to analyze impacts of different investment levels on performance – the pavement management system, and the bridge management system. The pavement management system can be used, for example, to predict the percentage of pavement in “poor” condition 10 years in the future, for a given level of annual investment between now and then. The 10-year period was selected because beyond this time-frame, there is significantly less confidence in the predictive models that are available.

The pavement and bridge management systems are currently being actively used to manage inventory information and store condition inspections. VTrans is now at the point for each of these systems where there is enough historical data to develop more accurate predictive performance models. Such models will allow the agency to better understand the likely changes in pavement and bridge condition given different future investment levels.

While VTrans continues to make progress towards improvement in its predictive capabilities, current pavement and bridge management system models (based on national data and expert judgment) have been used to provide a rough picture of the relationship between investment and performance.

In addition, the FHWA's national Highway Economic Requirements Analysis (HERS) model was run for Vermont's sample Highway Performance Monitoring System (HPMS) data in order to demonstrate how this model could be used in the future to supplement Vermont's understanding of the relationship between investment and highway performance. FHWA requires that all states collect a standard set of highway performance data in order to track the status of the nation's highway system over time. The HERS model takes HPMS data as its input, uses engineering standards to identify highway deficiencies, and then applies economic criteria to select the most cost-effective mix of improvements for systemwide implementation. HERS produces estimates of the costs of making these improvements. The HERS model predictions also include impacts on highway deficiencies (compared to standards), as well as changes in user costs (which are a function of travel time reductions, accident reductions, and speed changes). Because Vermont's HPMS dataset covers only a small sample of highways, and excludes rural minor collectors and all local roads, the HERS results need to be interpreted with caution. Supplementation of the Vermont HPMS data (using already existing data sources) is recommended to provide more meaningful results. The HERS model results are shown in Appendix B.

The remainder of this section presents the results of the tradeoff analysis conducted for pavements and bridges using the current management models. The results can be used for purposes such as estimating the future condition of the network if current funding levels are maintained; estimating the minimum funding required to maintain status quo performance conditions; and estimating the additional funding required to bring conditions up to a set performance target. It should be noted that these investment analyses do not take into account possible technological advances in highway engineering that could potentially decrease the costs of preserving/improving the system nor do they address the fact that the agency is continuing to improve the way it manages Vermont's highways. Note also that all of the costs are expressed in 2002 dollars, so to derive future year budget requirements they would need to be adjusted for inflation.

Pavement

VTrans' Pavement Management System is a data management and analysis tool containing information about the characteristics of each pavement segment on the Vermont State highway network. The system tracks changes in pavement condition over time based on annual field surveys. It can be used to develop pavement treatment strategies that maximize benefits given a budget constraint, and to understand future pavement performance that would result from different levels of investment.

The Pavement Management System was used to simulate pavement condition over a 10-year period, from 2002 through 2011, under varying assumptions about the size of the annual budget for pavement work. Separate scenarios were run for the three portions of the SHS defined above in Section 3.2 (Interstate, Non-Interstate Primary, and Off-Primary).

Detailed results of the analysis are shown in Figures 3.2 (Interstates), 3.3 (Non-Interstate Primary), and 3.4 (Off-Primary). Each of these figures show how pavement performance

would be expected to vary at the end of the 10-year analysis period for different annual investment levels.

Key findings of this analysis are summarized as follows:

- The Interstate Primary system accounts for 21 percent of the pavement two-lane miles² 30 percent of all travel (VMT) and 47 percent of the truck travel on the SHS. This system will require roughly \$12 million to \$13 million per year to maintain the same condition as today (both with respect to the percent of very poor miles and the travel-weighted average condition). At lower levels of investment, the pavement management system results show a sharp decline in average condition and a sharp increase in the percent of miles in very poor condition. Between 1998 and 2002, the average annual investment in Interstate pavements has been \$10 million. If this level of investment were to continue over the next 10 years, the results indicate that the average pavement condition index would decline from the current level of 79 (on a scale of 0 to 100) to 77, and the percent of very poor miles would increase from today's one percent to 10 percent.

Figure 3.2 Annual Pavement Investment versus Performance (2002-2011)
Interstate

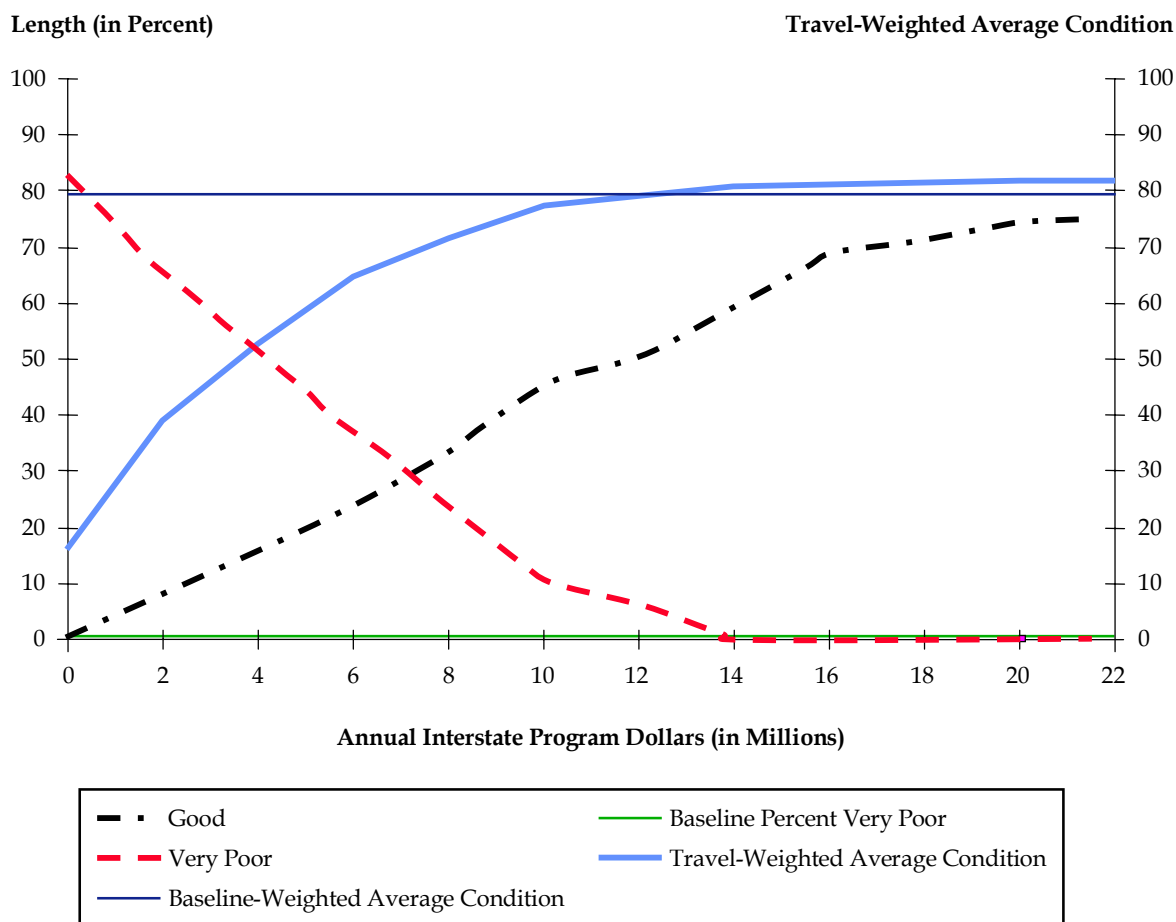
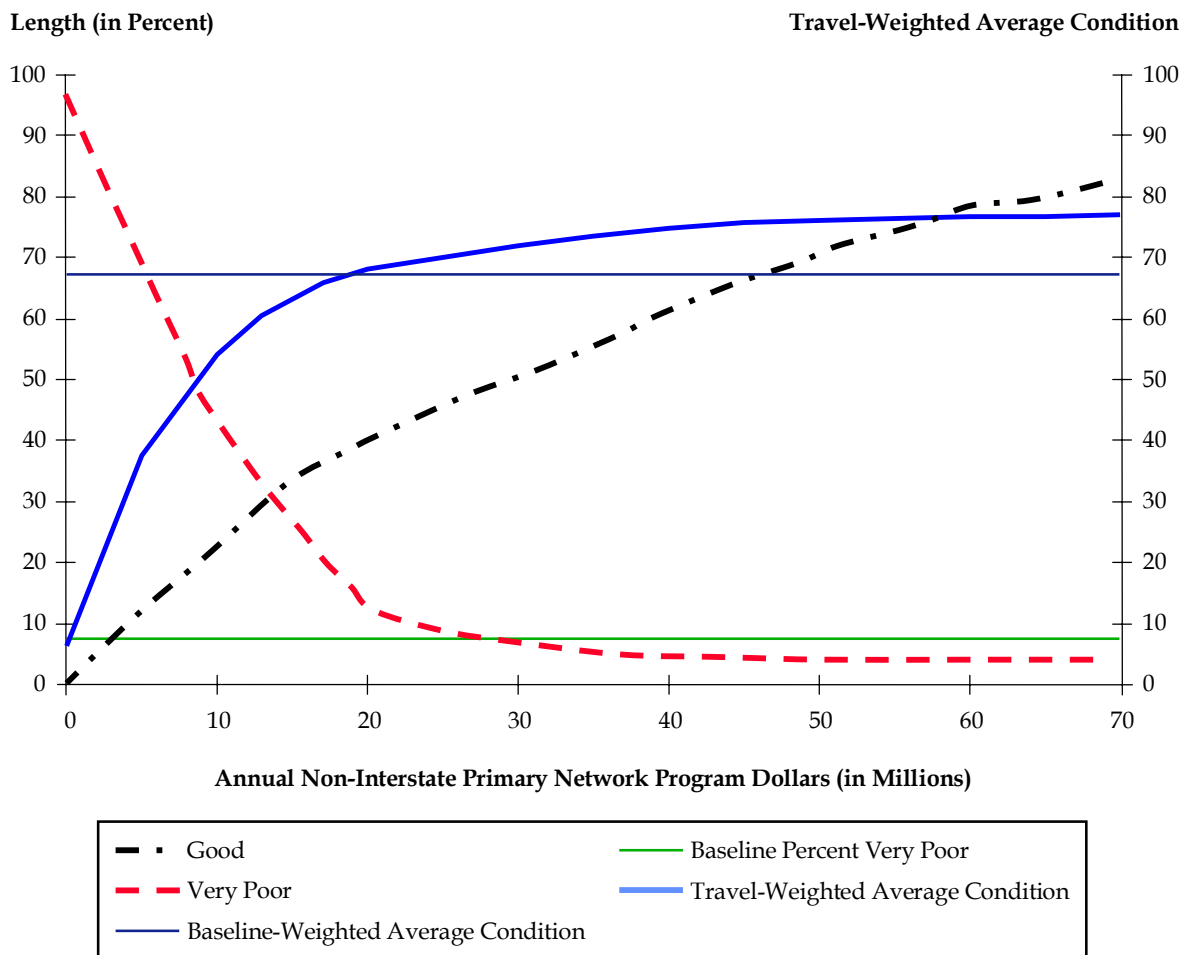
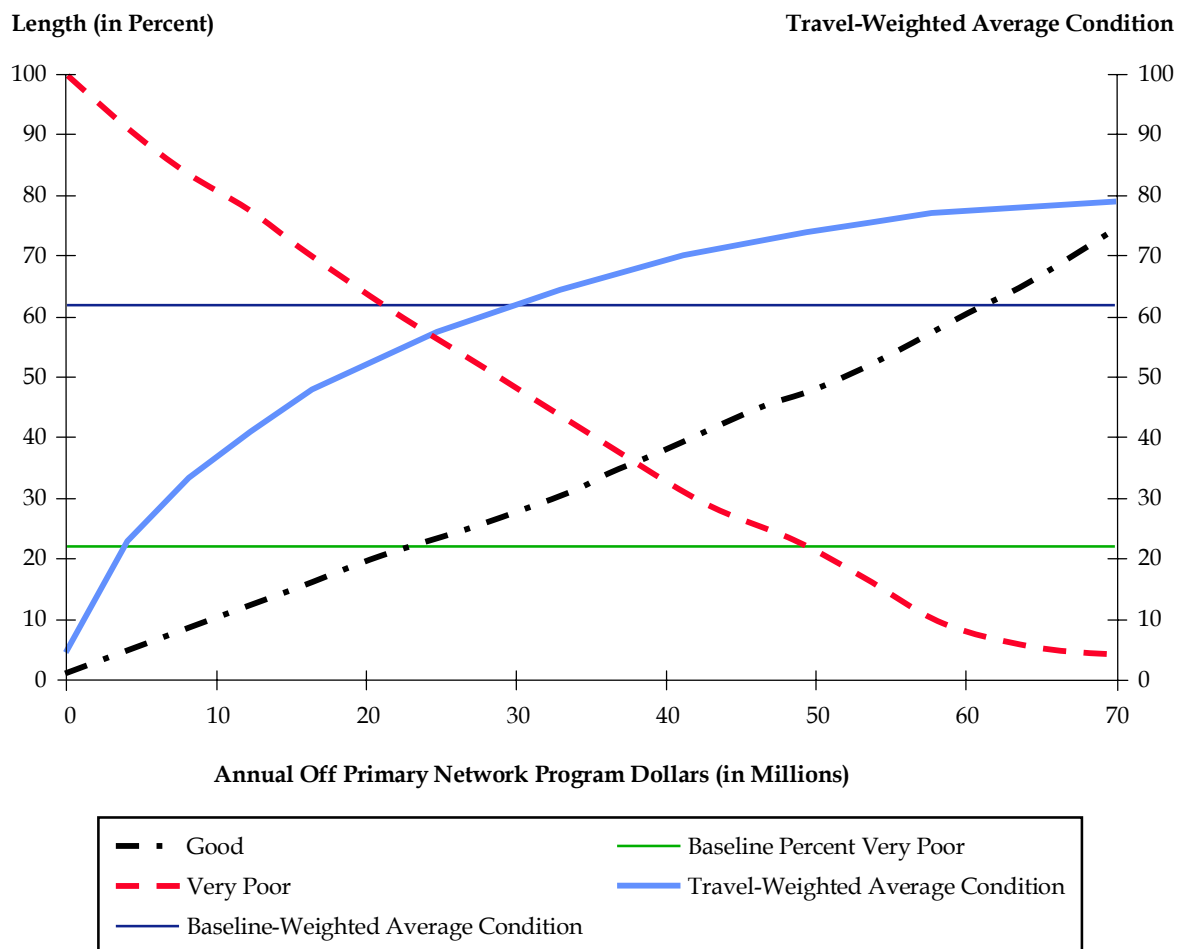


Figure 3.3 Annual Pavement Investment versus Performance (2002-2011)
Non-Interstate Primary Network



- The Non-Interstate Primary System accounts for another 21 percent of the SHS mileage, and carries 30 percent of the vehicle miles and 28 percent of the truck miles of travel on the SHS. To keep the percent of very poor miles at or below the current level of seven percent on this subnetwork, the Pavement Management System indicates the need for an annual investment of \$30 million. To maintain the current travel-weighted average condition level of 68, an annual investment of \$20 million would be required. The average level of investment for this subnetwork over the past five years has been \$11 million. If this funding trend were to continue over the next decade, the Pavement Management System predicts a decline in the travel-weighted average condition index to 56, with the percent of very poor miles rising to 40 percent.

Figure 3.4 Annual Pavement Investment versus Performance (2002-2011)
Off-Primary Network



- The Off-Primary System accounts for 58 percent of the SHS mileage, 40 percent of the vehicle miles, and 25 percent of the truck miles of travel on the SHS. To maintain the current travel-weighted condition index of 62, an annual investment level of \$38 million would be required. To maintain the current percentage of poor miles at the current level of 23 percent would require an investment of \$57 million annually. The five-year trend funding level for this subnetwork has been \$17 million annually. The predicted performance if this trend continued over the 10-year analysis period would be an increase in very poor pavements from 23 percent to 73 percent. The travel-weighted average condition would decline from the current level of 62 to 43.

Based on this analysis, four investment scenarios have been developed involving different annual investment levels and allocations across the three subnetworks. The first three scenarios (\$63 million to \$109 million) represent increased funding levels over the historical average; the fourth scenario represents maintaining roughly the same average funding for pavement as over the past five years (\$40 million).

- **Scenario 1: High Investment Level** – This scenario would improve pavement condition on all systems. The share of very poor miles would be negligible on the Interstate, five percent on the non Interstate Primary, and 21 percent on the Off-Primary Network. Average travel-weighted conditions would be 81 on the Interstate, and in the 73 to 74 range on the other two systems. This scenario would cost an average of \$109 million per year.
- **Scenario 2: Medium Investment Level** – This scenario would allow very slight deterioration of the Interstate system, but still keep this system in very good condition (three percent of the system in very poor condition; average travel weighted condition of 80). It would hold the share of Non-Interstate Primary miles in very poor condition to its current level (seven percent), but would improve the travel-weighted average condition on this network from 68 to 72. It would allow a moderate decline in the condition of Off-Primary system, both with respect to the share of very poor miles (from 23 percent to 30 percent) and with respect to the average travel-weighted condition (from 62 to 69). This scenario would cost an average of \$93 million annually.
- **Scenario 3: Low Investment Level** – This scenario is the same for Interstates as the previous scenario. It holds the travel-weighted average condition for the Non-Interstate Primary network to the existing level of 68, but does allow the share of very poor miles on this network to increase from seven percent to 12 percent. The Off-Primary network experiences significant declines in condition – 55 percent of its length would be in very poor condition, and the average travel weighted condition would decrease from 62 to 56. This scenario would cost an average of \$63 million per year.
- **Scenario 4: Current Funding Level** – This scenario is for an investment level roughly equal to the historical level (\$40 million annually). It allows significant deterioration on all three systems. The Interstate system would be maintained at the highest condition level; the Off-Primary would be in the worst shape, with 76 percent in very poor condition.

Table 3.5 compares the required annual funding for these scenarios by network level, and their performance outcomes in the year 2011.

Table 3.5 Alternative Pavement Investment Scenarios

Investment Scenario	Network Level	Funding (per year)	Percent Length in “Very Poor” Condition		Travel-Weighted Average Condition	
			Baseline	Projected	Baseline	Projected
1. High Investment Level <i>\$109 million/year</i>	Interstate	\$14 million	1%	0%	79	81
	Non-Interstate Primary	\$35 million	7%	5%	68	74
	Off-Primary	\$60 million	23%	21%	62	73
2. Medium Investment Level <i>\$93 million/year</i>	Interstate	\$13 million	1%	3%	79	80
	Non-Interstate Primary	\$30 million	7%	7%	68	72
	Off-Primary	\$50 million	23%	30%	62	69
3. Low Investment Level <i>\$63 million/year</i>	Interstate	\$13 million	1%	3%	79	80
	Non-Interstate Primary	\$20 million	7%	12%	68	68
	Off-Primary	\$30 million	23%	55%	62	56
4. Current Funding <i>\$40 million/year</i>	Interstate	\$10 million	1%	10%	79	77
	Non-Interstate Primary	\$15 million	7%	25%	68	63
	Off-Primary	\$15 million	23%	76%	62	40

Bridge

The analysis of bridge investment versus performance included the following three groups of long structures (over 20 feet in length) on Vermont’s SHS⁷:

1. Interstate Primary (314 structures);
2. Non-Interstate Primary (190 structures); and
3. State-owned structures on the SHS but off the Primary Network (530 structures).

This set of 1,034 bridges accounts for 96 percent of the bridges on the SHS. The remaining four percent are bridges off of the Primary Network that are locally or privately owned.

Two of the three structure performance measures were analyzed – the average health index, and the number of structurally deficient bridges. These measures were described

⁷ This analysis does not include 1,307 large culverts and large retaining walls that the agency is responsible for managing.

above in Section 3.3. Predictive capabilities for the third measure (number of restricted bridges) are not available in the bridge management system.

Rather than looking at performance at the end of the 10-year period as was done for the pavement analysis, the bridge analysis results are presented in terms of the average performance over the entire 10-year period. This is because the number of structurally deficient bridges exhibits considerable variation from year to year in the bridge management system simulation results and does not follow the same smooth trend line as pavement condition does. Looking at the result for the end of the 10-year period could be misleading.

Detailed results of the analysis are shown in Figures 3.5 (Interstates), 3.6 (Non-Interstate Primary), and 3.7 (Off-Primary). These figures show how the average bridge performance during the 10-year analysis period would be expected to vary for different annual investment levels. Because the bridge management system cost models have not been calibrated to historical data, the analysis was done using two sets of costs that represent likely low and high estimates. Results for the “low” cost assumptions are shown in the graphs below, but results for the “high” cost assumptions are reflected in the figures cited in the text.

Figure 3.5 Annual Bridge Investment versus Average 10-Year Performance Interstate Bridges (314)

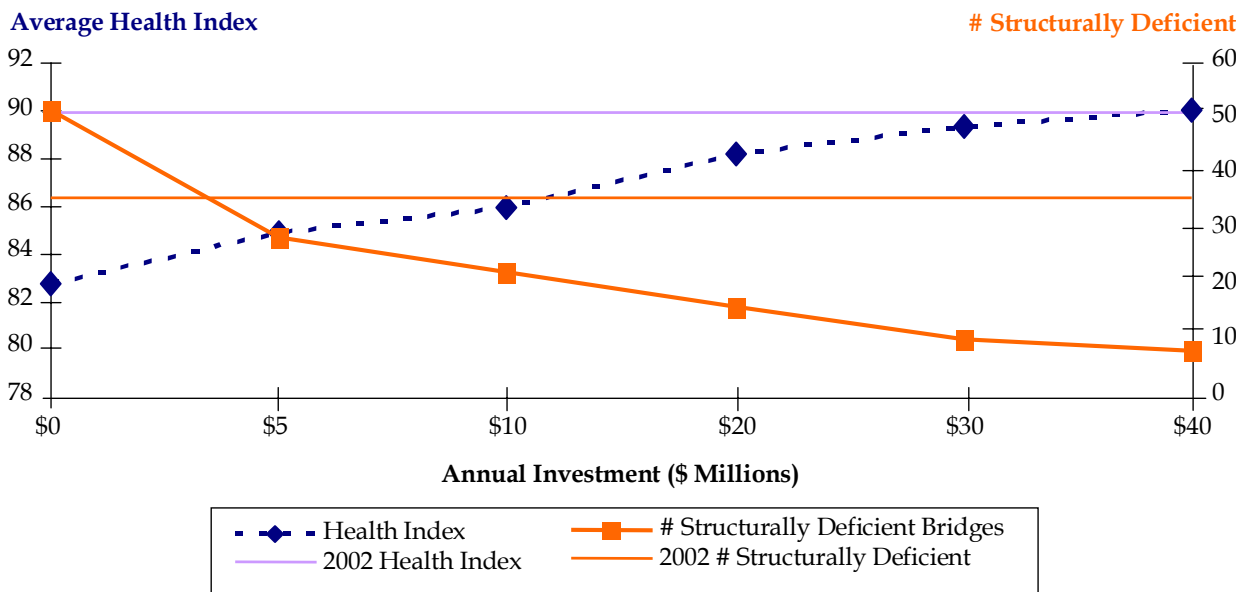


Figure 3.6 Annual Bridge Investment versus Average 10-Year Performance
Non-Interstate Primary Network Bridges (190)

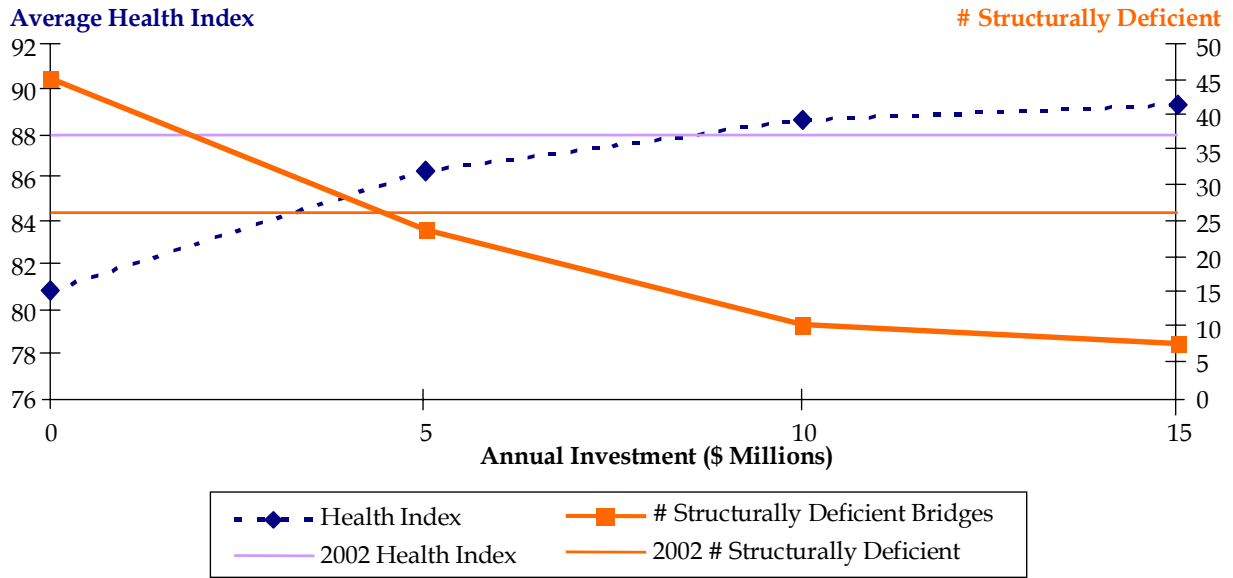
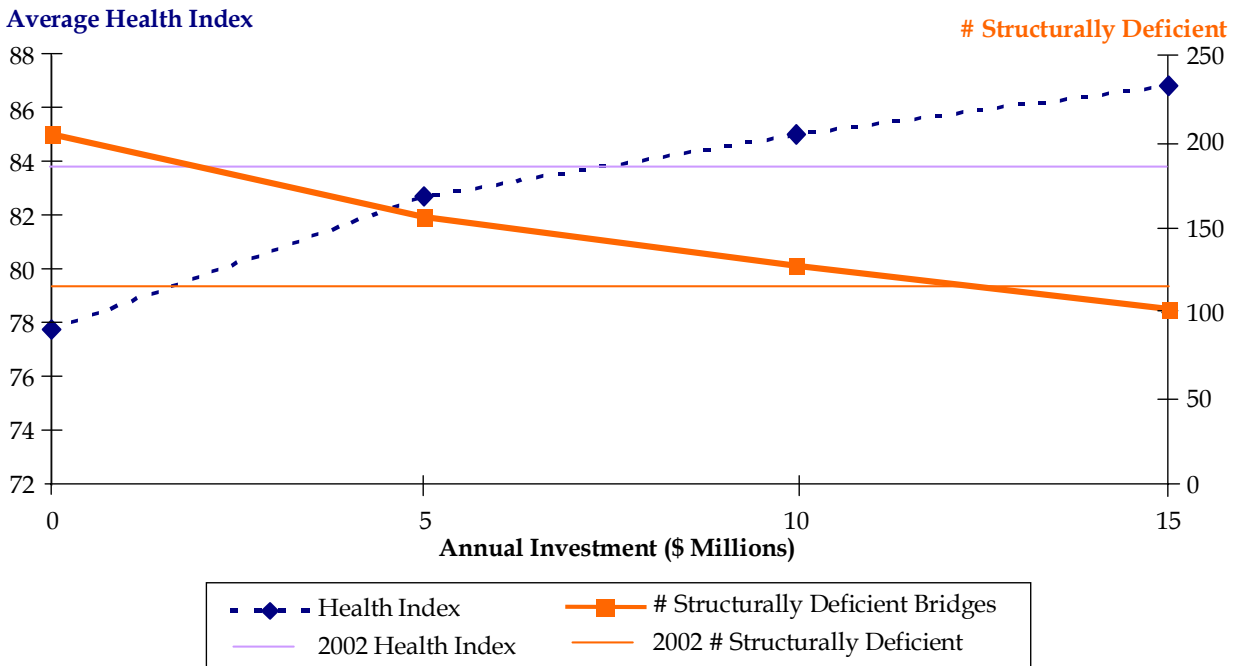


Figure 3.7 Annual Bridge Investment versus Average 10-Year Performance
State-Owned Off-Primary Network Bridges (530)



Key findings of this analysis are summarized as follows – ranges are shown based on the two sets of cost assumptions utilized:

- For Interstate bridges, the analysis indicates that an annual investment level between \$3 million and \$5 million would be required to keep the 10-year average number of structurally deficient bridges at the current level (36 of 313, or 11 percent). However, at least a \$40 million annual investment over the 10-year period would be required to maintain the 10-year average health index at the current level of 90. At the historical investment level between \$5 million and \$6 million per year⁸, the 10-year average health index would decline to the 84 to 86 range.
- For bridges on the Non-Interstate Primary Network, an annual investment level between \$4 million and \$5 million would be required to keep the 10-year average number of structurally deficient bridges at the current level (27 of 190, or 14 percent). An annual investment level of \$7 million to \$12 million would be required to maintain the 10-year average health index at the current level of 88.
- For state-owned bridges off of the Primary Network, \$12 million to \$14 million per year would be required to keep the 10-year average number of structurally deficient bridges from increasing over the current level (116 of 530, or 22 percent). An annual investment of \$7 million to \$10 million would be required to maintain a 10-year average health index equal to the current level of 84.

The historical investment level for non-Interstate SHS bridges over the past five years has been roughly \$11.6 million per year. If this amount were split evenly between the Non-Interstate Primary and the off-Primary networks, the result would be a slight (one point) decline in the 10-year average Health Index on both networks, a slight decrease in the 10-year average number of structurally deficient bridges on the Non-Interstate Primary network, and a fairly significant (30 percent) increase in the 10-year average number of structurally deficient bridges on the Off-Primary Network (from 116 to over 150).

Based on this analysis, four bridge investment scenarios have been developed involving different annual investment levels and allocations across the three subnetworks. The results for the “low” set of unit costs were used for these scenarios – therefore they represent an optimistic view of performance (using the higher cost assumptions would result in lower predictions of performance).

- **Scenario 1: High Investment Level** – This scenario includes sufficient funds to maintain the 10-year average health index for Interstate bridges at the current level (while reducing the 10-year average number of structurally deficient Interstate bridges down to three percent), and to make moderate improvements in the condition of Primary Network and Off-Primary Network bridges. This scenario would cost an average of \$70 million annually.

⁸ Based on an analysis of bridge projects between 1998 and 2002 – does not include bridge work done as part of highway projects that did not use federal “BR” funds.

- **Scenario 2: Medium Investment Level** – Maintaining the 10-year average performance at the current level on all of the three subnetworks. This scenario would cost an average of \$59 million annually.
- **Scenario 3: Low Investment Level** – Allow the 10-year average Interstate bridge health index to drop below the current average of 90 to 88 but reduce the 10-year average number of structurally deficient Interstate bridges to 16 (currently 38). Allow the remainder of the bridges on the Primary Network to deteriorate slightly with respect to average health index (decline of one point), while slightly reducing the 10-year average number of structurally deficient bridges. Maintain the current performance level off of the Primary Network, given that the number of structurally deficient bridges on that network is already quite high, and would increase considerably at lower investment levels. This scenario would cost an average of \$37 million per year.
- **Scenario 4: Current Funding Level** – This scenario assumes an investment level of \$18 million per year, split evenly across the three networks.

Table 3.6 compares the required annual funding for these three scenarios by network level, and their average performance outcomes over the 10-year analysis period.

Table 3.6 Alternative Bridge Investment Scenarios

Investment Scenario	Network Level	Funding (per Year)	Ten-Year Average Health Index	Ten-Year Average Number Structurally Deficient
1. High-Level Investment <i>\$70 million/year</i>	Interstate	\$40 million	90	8 (3%)
	Non-Interstate Primary	\$10 million	89	11 (6%)
	Off-Primary	\$20 million	89	77 (14%)
2. Medium-Level Investment <i>\$59 million/year</i>	Interstate	\$40 million	90	8 (3%)
	Non-Interstate Primary	\$7 million	88	27 (14%)
	Off-Primary	\$12 million	84	116 (22%)
3. Low-Level Investment <i>\$37 million/year</i>	Interstate	\$20 million	88	16 (5%)
	Non-Interstate Primary	\$5 million	87	24 (13%)
	Off-Primary	\$12 million	84	116 (22%)
4. Current Funding Level <i>\$18 million/year</i>	Interstate	\$6 million	85	27 (9%)
	Non-Interstate Primary	\$6 million	87	22 (12%)
	Off-Primary	\$6 million	83	150 (28%)

