

NCHRP Project 20-24(79)
**Specifications for a National Study of the Future 3R,
4R, and Capacity Needs of the Interstate System**

prepared for

American Association of State Highway and Transportation Officials
(AASHTO)

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December 2013

The information contained in this report was prepared as part of NCHRP Project 20-24,
Task 79, National Cooperative Highway Research Program.

SPECIAL NOTE: This report **IS NOT** an official publication of the
National Cooperative Highway Research Program, Transportation Research
Board, National Research Council, or The National Academies.

Acknowledgements

This study was conducted for the American Association of State Highway and Transportation Officials (AASHTO), with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 20-24(79), *Specifications for a National Study of the Future 3R, 4R, and Capacity Needs of the Interstate System*. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 20-24 is intended to fund quick response studies on behalf of AASHTO and state DOT leadership. The report was prepared by Deb Miller, Susan Binder, Hugh Louch, and Kelsey Ahern of Cambridge Systematics, Inc. and Hal Kassoff and Steve Lockwood of Parsons Brinckerhoff . The work was guided by a technical working group. The project was managed by Andrew Lemer, NCHRP Senior Program Officer.

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Executive Summary

The Interstate Highway System (IHS) provides the backbone of the national transportation system. Although the system makes up only 1.2 percent of the country's public road mileage, it handles nearly 25 percent of the total vehicle miles traveled (VMT) annually and almost 40 percent of the nation's total truck traffic.¹ However, what was once a premier system that stood as a symbol of American growth and economic vigor is showing its age.

This research effort was initiated to identify and evaluate methodologies capable of comprehensively estimating the costs and benefits of various levels of investment in the IHS for 3R², 4R³, and new capacity⁴ needs as well as to consider the benefit of parallel investments in systems operations and new technology.

PROPOSED PROJECT FRAMEWORK

The recommended framework for estimating the full range of future needs for the IHS employs a layered approach that builds in flexibility to adapt to alternative visions for the system. This framework has three principal characteristics:

- **Modular** - For the purposes of estimating costs to meet 21st century transportation demand, potential IHS system needs can be categorized into four objective-related program components:
 - Preserving⁵ the IHS System,
 - Operating the IHS assets efficiently,
 - Growing the IHS, and
 - Harnessing Technologies to Improve the IHS.

¹ Federal Highway Administration, Highway Statistics 2011.

² 3R refers to resurfacing, restoration, and rehabilitation as defined in the Federal-Aid Highway Act of 1976.

³ 4R refers to resurfacing, restoration, rehabilitation, and reconstruction as defined in the Federal-Aid Highway Act of 1981.

⁴ New capacity, as used throughout this report, is defined as projects that increase capacity of the existing IHS through expansions, lane additions, extensions, and interchange improvements.

⁵ Preservation, as used throughout this report, is intended to capture the full range of treatments to restore the existing IHS system, including resurfacing, rehabilitation, and reconstruction.

This approach reflects a logical progression of needs, moving from basic preservation and operational improvements toward the more discretionary investments related to systems additions and technology enhancements. This modular approach allows decision-makers to compare the costs of various choices and make more informed decisions about how the nation would best be served by alternative investments in the IHS.

- **Performance-Based** – Passage of the federal Moving Ahead for Progress in the 21st Century Act (MAP-21) has emphasized the use of performance management to inform the investment of resources in projects that collectively contribute toward the achievement of national, statewide and regional goals. Associating the various Interstate components with their performance attributes is consistent with the trend toward performance management approaches at the state and metropolitan level. A base assumption of this study is that at least one set of targets would be set and evaluated.
- **Scalable** – The proposed framework is designed to be replicable and iterative such that analysts might adjust levels and mixes of investments in the IHS according to alternative visions (for example the extent of potential capacity additions) or varying performance targets or ranges of funding scenarios. By varying assumptions about the need for added capacity or the priority for investment made in operational improvements, the consequences of strategies can be weighed against the benefits to be gained and the costs to be borne.

ALTERNATIVE METHODOLOGIES

Four alternative methodologies that could be used to assess the investment needs of the IHS were defined and compared:

- **Method 1: Model Needs with Existing Analytic Tools** - This established methodology relies on the use of existing analytic tools used in FHWA studies (e.g., Condition and Performance Report), primarily the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS). To ensure the analysis covers the majority of the program components, Method 1 supplements these models by including proven analytics such as the ITS Deployment Analysis System (IDAS) and the Transportation Operations Benefit Cost (TOPS-BC) analysis tool.
- **Method 2: Case Study Approach to Develop Sample Segment Cost Estimates** - This methodology consists of developing cost estimates for sample segments of the IHS using a forensic/case study approach, looking in detail at rehabilitation/replacement cost on sample segments, and then applying the estimates on a system-wide scale. A national cost estimate would be based on expanding a representative sample of segments to

estimate the costs of achieving the performance targets established for the study.

- **Method 3: Supplement Analytic Tools with Case Studies (Hybrid of Methods 1 and 2)** - A hybrid of Methods 1 and 2, this methodology would adjust and/or confirm the investment needs estimated by analytical tools (HERS, NBIAS, etc.) with selected case studies as described in Method 2.
- **Method 4: State-Assessed Needs Combined with Unit Costs** - Using national cost estimates for a list of standard improvements in each program component, individual states would be asked to provide estimates of applicable IHS mileage. State estimates would then be aggregated to a national total.

RECOMMENDATION

Taking all of the factors into consideration, the research team recommends Method 3, a hybrid of Methods 1 and 2. It is applicable for estimating the needs of three of the four program components: Preserving our Transportation System, Operating Our Assets Efficiently, and Growing our Transportation Infrastructure. Method 3 utilizes existing analytic models such as HERS and NBIAS to estimate IHS needs. While there are some concerns about data adequacy and potential complexity, these analytic models are the best tools available and have been shown to yield plausible results within the stated limits of their applicability. Utilizing the hybrid method to supplement the models with case studies will focus on addressing these perceived limitations in the analytic models.

Harnessing Technology to Improve our System, the fourth program area will require its own tailored approach. With inherent uncertainty about new and improved technologies that may emerge over the coming decades, estimating the likely investment needs of harnessing technology and the impact of technology on existing needs will require additional understanding and insights into the leading candidates for technological advancements for developing, deploying, and managing IHS elements.

KEY PARTICIPANTS

It is important that this study be conducted in a collaborative manner. To be successful, the study needs to advance an understanding of the technical issues while presenting politically realistic and sensitive findings. To accomplish those two goals, the following describes the key participants in the study and their roles and responsibilities for the study:

- Current and future owners, operators, and users of the system (including the private sector stakeholders) need to be included in the study process;

- The institutions that are the sources of data for the information needed for the study (state departments of transportation [DOTs] and AASHTO as well as FHWA) should be part of the process;
- The Transportation Research Board (TRB) represents a valuable neutral sponsor lead for the study using either the NCHRP or Policy Studies vehicles. It is suggested that a special blue ribbon panel of national experts willing to participate and who would be precluded from performing the study would be constituted as an oversight panel, supported by technical subgroups in each of the specialty areas;
- Considering that a robust institutional memory exists in the highway industry in applying the techniques involved in implementing the study, this community should be consulted to build on the lessons learned from past national needs assessments.

COST AND TIME TO DO THE STUDY

Without a fully developed project scope and work plan for a major 3R, 4R, and new construction needs study of the IHS, it is difficult to accurately estimate the cost and time needed to undertake such a study. However, a reasonable estimate is an important consideration for determining if such a study should be conducted. The following discussion provides the basis for the estimates made by the research team.

Time

If the analyses for the new study were constrained to the existing IHS only, it is reasonable that sufficient case studies could be conducted, their findings incorporated into model improvements, and the final modeling work executed in a 18-24 month period. If the scope of the new study expands beyond the IHS, it would be less likely that sufficient case studies and modeling changes could be accomplished in that time period, and the study period would likely extend to a 24-30 month period.

The following provides a realistic breakdown of a possible project timeline:

- Two to three months of work plan refinement (including panel confirmation of goals and desired alternative outcomes);
- Nine months to conduct a robust set of case studies;
- Followed by two months of model design/adaptation;
- Followed by six months of model simulations and preliminary report drafting;

- Before the report would be final, there is likely to be an extended review and feedback cycle both in industry and policy arenas. This could easily add another six months.

Based on these assumptions, the estimated amount of time needed to conduct a study of the 3R, 4R, and new construction needs of the IHS is two to two-and-one half years including review, final drafting, oversight by the panel and external review.

Cost

For comparison purposes, and as a way to begin to understand what the likely cost of a major IHS study might be, the research team considered the cost of preparing the biennial needs study for the *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* report to Congress (known as the C&P report).

The investment made by FHWA to support and conduct the C&P report has been in the range of \$1 to \$1.5 million per year, varying depending on the level of innovation from the previous cycles. It is assumed that with the cooperation of the FHWA in doing this study that there will be some analytical efficiencies.

Using these assumptions, the research team's estimated cost to complete a major IHS study is \$3-4 million.

2.0 Background

The Interstate Highway System (IHS) provides the backbone of the national transportation system. Although the system makes up only 1.2 percent of the country's public road system, it handles nearly 25 percent of the total vehicle miles traveled (VMT) annually and almost 40 percent of the nation's total truck traffic.⁶ However, what was once a premier system that stood as a symbol of American growth and economic vigor is showing its age.

Much of the IHS is still "first generation" and as a system, it has not kept up with the growing and shifting demands of the 21st century. The need for ongoing maintenance and preservation actions and, increasingly, complete reconstruction of the system has grown. The capacity of the IHS and its configuration have not kept up with the increasing and changing travel demands. The system is substantially unmanaged and operates below its intended capacity and safety – and the potential of new technology to maximize service and minimize costs has barely been tapped. A 21st century IHS fully serving the nation's transportation needs for the next 50 years will require far more than simply maintaining it in its current condition and configuration.

As the owners and operators of the System, state departments of transportation (DOTs) have conducted regular maintenance and reconstruction but that investment has not been sufficient to avoid considerable functional and physical obsolescence. Traffic projections in many regions grossly underestimated the popularity of the IHS for commercial use, exacerbating the punishment that the system has taken and the mismatch between design life and service. In many locations, pavement subgrades and base layers date back to the original construction of the Interstate (or before), driving up today's ongoing annual maintenance and rehabilitation needs and limiting the life of treatments. Many bridges originally forecasted to last 50 years remain in use well beyond their design life with no plans for reconstruction in sight.

At the same time, continued growth and development in many parts of the country – both automobile and commercial -- are straining existing capacity. Some metropolitan regions -- developed substantially since World War II -- were not served as part of the original Interstate system and suggest potential needs for system expansion. The IHS has lost considerable capacity, reliability and safety to growing congestion and incidents. There is now the opportunity to capitalize fully on rapidly developing intelligent transportation systems (ITS) technology and transportation systems management and operations concepts -- as well as tolling and managed lanes -- to recapture lost level of service.

⁶ Federal Highway Administration, Highway Statistics 2011.

New technology also provides a wide range of additional opportunities to improve customer service and convenience, to reduce construction and maintenance costs, and to bring the IHS fully up to modern standards. For those technologies that are known today, the current gap between best practice and prevailing practice is significant; so just by advancing the norm from the state of the practice to the state of the art, large gains in efficiency and effectiveness might be realized. Even where performance increments may be modest on a segment basis, system-wide applications of improved technologies may provide an important level of aggregate benefits not available from other network-level strategies. As new systems and technologies become available (some involving vehicle technology) higher levels of safety, operational and economic performance should be taken into consideration in any study estimating the needs of a future IHS.

Congress has long recognized the critical importance of the IHS to the nation's economic growth and quality of life through continued investment in IHS resurfacing, restoration, rehabilitation, and reconstruction. To guide these actions, requirements were enacted for estimating investment needs to maintain and improve IHS conditions and performance in the form of the Federal Highway Administration (FHWA) biennial "Conditions and Performance" reports. This continuing series offers an important point of reference in considering levels of Federal investment contemplated during authorization cycles.

These analyses and the tools used to estimate the changing IHS investment needs have evolved since their initial application. At the same time, however, the range of relevant policy considerations and approaches have expanded beyond the condition and performance of the existing network to questions related to operational management, system expansion, major reconstruction costs and the potential of new technology regarding service and costs. However the existing tools for estimating need are constrained by a legacy of narrow technical focus, complex methodology and significant data requirements. As a consequence, the findings using the analysis approach and tools available today do not fully capture the costs of fully restoring and improving the IHS. In particular, the tools are not able to assess changes in the system's scope or capacity that might improve the safety, reliability, efficiency, or security of the transport services it supports. In addition, the ability of the tools to adequately reflect long-term deterioration and reconstruction needs triggered by stressors other than traffic loadings is questionable.

The current environment, with declining revenues and a common "no new tax" philosophy, makes investing in major infrastructure initiatives challenging. Transportation needs to be considered in the context of the full range of national, state, and local goals and priorities, as well as in the context of the economic and personal connectivity benefits that can be expected at various scales. Therefore, a

future national needs assessment should not only take into account the costs for future preservation⁷ and selective expansion of the IHS, but should also consider emerging technologies and operational strategies that may create greater efficiency and therefore greater benefits to users.

This research activity was initiated to identify and evaluate methodologies capable of comprehensively estimating the costs and benefits of various levels of investment in the IHS for 3R⁸, 4R⁹, and new capacity¹⁰ needs as well as to consider the benefit of parallel investments in systems operations and new technology.

This Final Report presents the findings and recommendations of the specifications study. It presents four alternative methodologies that could be used singularly or in combination to estimate national IHS needs and assesses the strengths, weaknesses, data needs, and other resource requirements of each. Based on this assessment, the research team recommends a preferred approach for estimating the investment needs of the IHS, describes the major work elements required, assesses the data needs and quality of available data for such a study, and addresses the time and costs required for the study's completion. The products of this work are intended to inform the Congress, AASHTO leadership, and FHWA and provide them with a basis for committing to and undertaking such a study.

⁷ Preservation, as used throughout this report, is intended to capture the full range of treatments to restore the existing IHS system, including resurfacing, rehabilitation, and reconstruction.

⁸ 3R refers to resurfacing, restoration, and rehabilitation as defined in the Federal-Aid Highway Act of 1976.

⁹ 4R refers to resurfacing, restoration, rehabilitation, and reconstruction as defined in the Federal-Aid Highway Act of 1981.

¹⁰ New capacity, as used throughout this report, is defined as projects that increase capacity of the existing IHS through expansions, lane additions, extensions, and interchange improvements.

3.0 Overview

The objective of this project is to develop and evaluate alternative approaches for a future study to estimate the 3R, 4R, and new capacity needs required to ensure that the IHS will continue to meet the nation's demands for transportation services well into the future. In addition, it provides methods related to estimating the need for and benefit from aggressive systems management and operations approaches and from the implementation of other new technology applications.

To meet this objective, the study options include descriptions of the major work elements required, an assessment of data needs and of the quality of the available data, estimates of time and costs required for the study's completion, consideration of study participants, and the organizational responsibilities for conducting such a study. The product of this project is intended to inform AASHTO leadership and USDOT regarding the study options, likely payoff from an improved IHS, the time frame needed to conduct the study, and the likely cost of the study.

Based on early discussions with the Study Panel it was agreed that an important objective of this project should be to develop an approach for a national IHS needs study that is flexible enough to allow decision-makers to consider multiple investment strategies and to make tradeoffs among investment options based upon the magnitude and distribution of benefits and impacts of alternative improvement strategies and their cost.

The research team conducted the work for this study in three phases:

- **Phase I**, summarized in Technical Memorandum #1, included interviews with three state DOTs to understand the approaches, methodologies, and tools that are used to estimate interstate (and other) system needs at a state level. The Memorandum also provided a critical review of existing analysis tools and past studies conducted to estimate national transportation system needs and outlined a flexible, modular framework for estimating IHS system needs.
- **Phase II**, summarized in Technical Memorandum #2, defined four alternative methodologies that could be used singularly or in combination to estimate national IHS needs for preservation, operations, expansion and new technology applications -- and assessed the strengths, weaknesses, data needs, and other resource requirements of each. Based on this assessment, the research team recommended a preferred approach for estimating the investment needs of the IHS.
- **Phase III**, documented in this Final Report, provides a more detailed plan for implementing the recommended approach for future needs studies, including data and analytical considerations, estimates of time and costs

required, study participants, and the appropriate organizational responsibilities. The product of this project is intended to inform AASHTO's leadership and USDOT's consideration of future needs study options.

3.1 STUDY STRUCTURE

A study of future IHS needs must necessarily compare where the system is now with a desirable future. Therefore a critical component of the study will be to articulate alternative perspectives or characteristics for some future time period that in turn determines a methodological framework capable of responding to the alternative visions. The very process of articulating the various components of alternative future states and their estimated costs can, in itself, help to inform, clarify and define a clearer national vision for national transportation investment.

The proposed framework for estimating the full range of future needs for the IHS employs a layered approach that builds in flexibility to adapt to alternative visions for the system. This framework has three principal characteristics:

- **Modular** - For the purposes of estimating costs to meet 21st century transportation demand, potential IHS system needs can be categorized into four objective-related program components:
 - Preserving the IHS System,
 - Operating the IHS assets efficiently,
 - Growing the IHS, and
 - Harnessing Technologies to Improve the IHS.

This approach reflects a logical progression of needs, moving from basic preservation and operational improvements toward the more discretionary investments related to systems additions and technology enhancements. This modular approach allows decision-makers to compare the costs of various choices and make more informed decisions about how the nation would best be served by alternative investments in the IHS. By using this approach, decision-makers can more readily answer a variety of "what if" questions, such as "what are the relative benefits, costs, and impacts of varying levels and mixes of investment in the IHS?"

As part of a modular strategy, each of these program components can be estimated individually (while recognizing the interrelationships and overlap among the components in the real world) and compiled to define an overall investment level for the IHS under a variety of scenarios.

- **Performance-Based** - Passage of the Federal Moving Ahead for Progress in the 21st Century Act (MAP-21) has emphasized the use of performance management to inform the investment of resources in projects that collectively contribute toward the achievement of national, statewide and regional goals. Associating the various interstate components with their

performance attributes is not only consistent with the trend toward performance management approaches at the state and metropolitan level, it can be used as well to articulate goals for the IHS at the national level. The identification of costs to achieve a certain level of pavement quality or accomplish an economic goal through selective capacity additions to the IHS can help to define the synergies and potential trade-offs among goals at various target levels of investment.

- **Scalable** – The proposed framework is designed to be replicable and iterative such that analysts might adjust levels and mixes of investments in the IHS according to alternative visions (for example the extent of potential capacity additions) or varying performance targets or ranges of funding scenarios. By considering differing assumptions about the need for added capacity or varying the assumption about the priority for investment made in operational improvements, the consequences of varying strategies can be weighed against benefits to be gained and the costs to be borne.

Table 3.1 summarizes the framework, identifying the underlying goals, performance measures, and strategies that could drive potential investment decisions for each program component. Each goal and goal mix suggests likely, specific performance measures which in turn imply a mix of “tools “ and IHS improvement strategies that – in varying degrees -- support the desired performance. Adjusting the assumptions regarding goals and performance targets, or other variables will result in different estimates of total needs. The approach is also capable of incorporating tiered performance targets that can be used to vary standards for different portions of the system (based on traffic volume, freight needs, geography, etc.), as desired. The approach also allows for levels of risk to be considered and assessed.

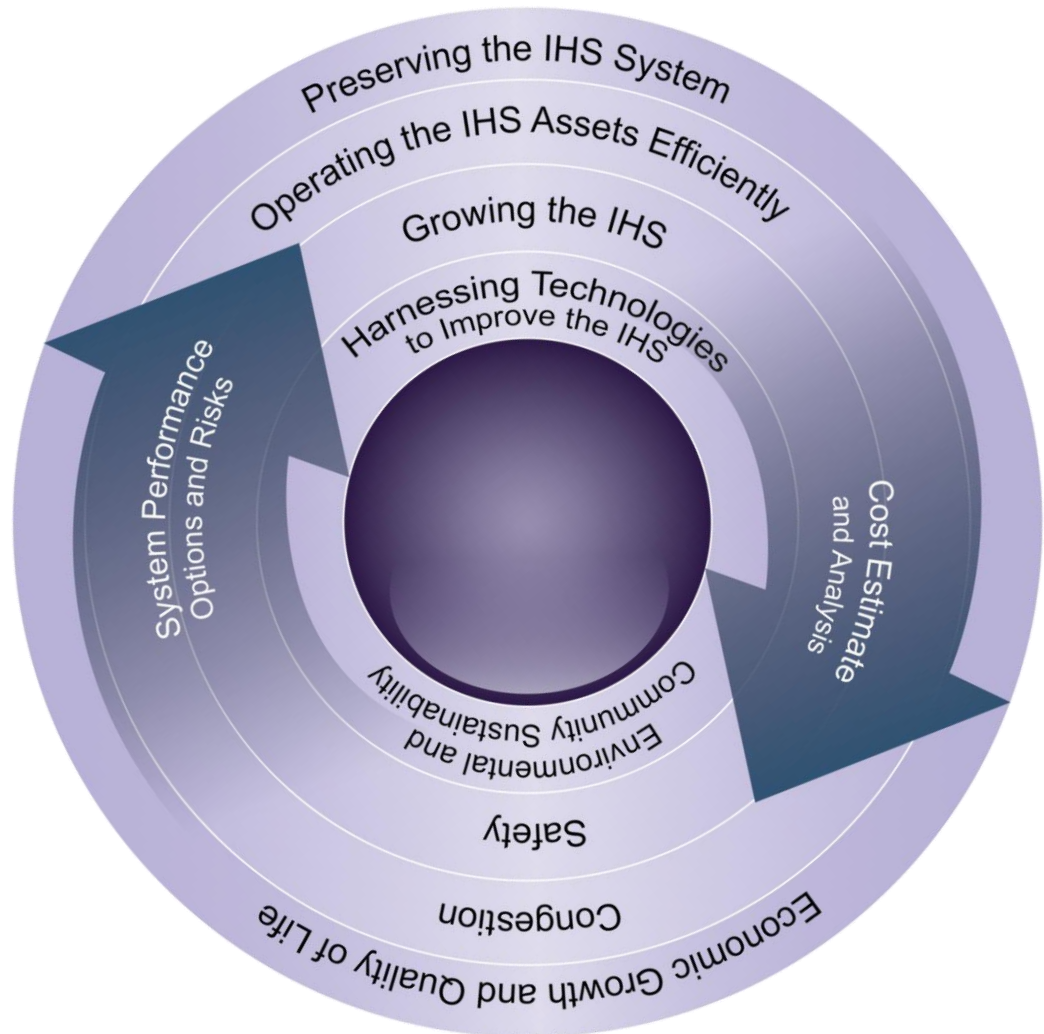
Table 3.1 Four Program Components for IHS Investment

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology to Improve the IHS
What are Our Goals?	<ul style="list-style-type: none"> • Protect the IHS investment by restoring and preserving the existing system • Restore the unique value and functional performance of the IHS as the world’s premier highway system • Improve the safety and reduce vehicle maintenance costs of IHS travel • Improve U.S. economic performance 	<ul style="list-style-type: none"> • Fully utilize all of the existing roadway capacity thus capturing the full value of the IHS • Improve traveler safety, comfort and convenience • Empower travelers by providing them with real time information. 	<ul style="list-style-type: none"> • Improve U.S. economic performance and competitiveness by investing in needed IHS expansions • Add and improve IHS interchanges needed to serve a growing economy and population. • Expand the IHS to support population and traffic growth, freight traffic, and military needs 	<ul style="list-style-type: none"> • Manage demand for IHS travel(passenger and freight) • Maximize effective capacity of existing infrastructure/ROW • Reduce travel time and increase travel time reliability • Reduce maintenance and operational costs • Minimize or eliminate crashes • Provide information for roadway management and maintenance • Improve traveler and vehicle information services
How Can We Measure Success?	<p>Sustained achievement of performance targets for:</p> <ul style="list-style-type: none"> • Bridge conditions • Pavement conditions • Well maintained pavement marking, lighting, and signage • High driver satisfaction 	<p>Sustained achievement of performance targets in:</p> <ul style="list-style-type: none"> • Reduced levels and duration of traffic congestion • Improved travel times and system reliability • Reduced incident response times • Reduced fatalities, serious injuries, and crashes • High driver satisfaction 	<p>Sustained achievement of performance targets in:</p> <ul style="list-style-type: none"> • Reduced time lost to traffic congestion • Improved system reliability • Travel time and shipping cost savings • Economic, social and environmental sustainability • Societal equity in distribution of benefits and impacts 	<p>Measures will vary based on the technologies but may include:</p> <ul style="list-style-type: none"> • Reduced traffic congestion • Improved travel times and speeds • Improved system reliability • Reduced incident response times • Reduced fatalities, serious injuries, and crashes • High driver satisfaction

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology to Improve the IHS
What Are the Tools to Achieve Success?	<ul style="list-style-type: none"> • Bridge preservation and replacement projects • Pavement preservation and reconstruction projects • Drainage repair and replacement projects • Replacement and upgrades of lighting, signage, and pavement markings • Safety enhancements to protect travelers 	<ul style="list-style-type: none"> • Advanced traffic management • Integrated corridor management • Demand management strategies • ITS technologies • Safety countermeasures • Incident response program improvements • Managed lanes • Enhanced enforcement 	<ul style="list-style-type: none"> • Capacity expansion projects including lane additions and new IHS segments • Reconstruction/expansion of outdated interchanges and new interchanges where population and economic growth need service • Environmental and economic analysis • Context sensitive approach to project development and delivery 	<ul style="list-style-type: none"> • Variable speed limits • Long lasting life-cycle materials • Rapid construction techniques • Remote sensing for conditions assessment and response • Substitution of in-vehicle signing for roadway communications • Vehicle-based systems which allow closer vehicle spacing; thus reducing the need to increase capacity, collision and run off the road avoidance technologies • Vehicle-based probe information for traffic management, roadway condition, and information • Traveler and in-vehicle information and other traveler assurance services

Figure 3.1 suggests the interactive, iterative nature of the proposed modular framework – and its contrast with the traditional national needs studies. Goal-related performance targets can be used as the basis for estimating the level of investment in the strategy tools needed to restore the existing system, maximize operational efficiency, expand/extend the system where appropriate, and harness new technologies – singly or in any mix. Analysts can then compare the costs of these improvements against the impacts on national goals (economic growth, safety, etc.); which can then re-inform system performance expectations and investment needs. Similarly, the approach recognizes the inherent interactions between program components; i.e., investments in one component may influence investment needs of another component. This proposed framework recognizes these interactions and incorporates them as part of a feedback loop process.

Figure 3.1 Linking Investment Needs with Performance



3.2 ASSESSMENT OF ALTERNATIVE METHODOLOGIES

In Phase I, the research team conducted an assessment of two existing analysis tools, the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS), and two data sources, the Highway Performance Monitoring System (HPMS) and the National Bridge Inventory (NBI), that have been used in several national efforts to estimate transportation investment needs. These methodologies have inherent strengths and weaknesses dependent on the proposed IHS goals and performance targets as suggested by their application as part of previous needs studies.

In light of today's policy context and constraints – and the expanded range of relevant improvement strategies -- additional methodologies and data sources are needed. Therefore, the research team defined and compared four alternative methodologies that could be used to assess the investment needs of the IHS:

- **Method 1: Model Needs with Existing Analytic Tools** - This established methodology relies on the use of existing analytic tools previously used in FHWA studies, primarily the HERS and the NBIAS. To ensure the analysis covers the majority of the program components, Method 1 supplements these models by including proven analytics such as the ITS Deployment Analysis System (IDAS) and the Transportation Operations Benefit Cost (TOPS-BC) Desk Reference and companion analysis tool.
- **Method 2: Case Study Approach to Develop Sample Segment Cost Estimates** - This methodology consists of developing cost estimates for sample segments of the IHS using a forensic/case study approach, looking in detail at rehabilitation/replacement cost on sample segments, and then applying the estimates on a system-wide scale. A national cost estimate would be based on expanding a representative sample of segments to estimate the costs of maintaining conditions and performance.
- **Method 3: Supplement Analytic Tools with Case Studies (Hybrid of Methods 1 and 2)** - A hybrid of Methods 1 and 2, this methodology would adjust and/or confirm the investment needs estimated by analytical tools (HERS, NBIAS, etc.) with selected case studies as described in Method 2.
- **Method 4: State-Assessed Needs Combined with Unit Costs** - Using national cost estimates for a list of standard improvements in each program component, individual states would be asked to provide estimates of applicable IHS mileage. State estimates would then be aggregated to a national total.

The four methodologies do not have identical purposes or scope although there are overlaps as well as potentials for promising combinations. As summarized in Table 3.2, the methodologies differ with regard to their ability to address specific improvement strategies that may be part of policy or program considerations. They also differ in their reliance on existing versus new data, network sampling versus case studies, scalability, robustness, accuracy, and perceived systematic

bias. Appendix A includes an expanded list of strengths and weaknesses for each methodology.

The research team assessed the feasibility and benefits of applying each of the methods to the four program components described in Section 2.1. Because a given methodology is more effective for certain program components than for others, the team considered options for mixing and matching the most appropriate methods for estimating the needs associated with the different components. Appendix A includes a table that outlines a proposed approach for each methodology and each program component, comparing data needs, level of effort, and the likely reliability of the resulting cost estimates.

Table 3.2 Summary of Alternative Methodologies for Estimating IHS Investment Needs

	METHOD 1: MODEL NEEDS WITH EXISTING ANALYTIC TOOLS	METHOD 2: CASE STUDY APPROACH TO DEVELOP SAMPLE SEGMENT COST ESTIMATES	METHOD 3: SUPPLEMENT ANALYTIC TOOLS WITH CASE STUDIES (HYBRID OF METHODS 1 AND 2)	METHOD 4: STATE-ASSESSED NEEDS COMBINED WITH UNIT COSTS
Overall Strengths	<ul style="list-style-type: none"> • Well-established methodology • Most data are available and reasonably up to date 	<ul style="list-style-type: none"> • Can select segments that contribute significantly to IHS needs • “Tells the story” of IHS needs, increasing transparency and potential acceptance of findings 	<ul style="list-style-type: none"> • Case studies could be used to adjust the models’ parameters and data • Helps to improve understanding and credibility of national needs 	<ul style="list-style-type: none"> • Simple solution that does not rely on models • Draws from in-depth knowledge and expertise of state DOTs for credibility • Provides a reasonable state and national cost estimate
Overall Weaknesses	<ul style="list-style-type: none"> • Limited applicability to non-preservation or capacity needs • “Black Box” perception • Unable to clearly account for replacement costs 	<ul style="list-style-type: none"> • Challenging to select and expand a statistically valid sample of segments • Extensive and in-depth case studies required to cover range of conditions • Not suitable for estimating new links • Variability among state agencies related to cost and data collection • Perception that no two states are alike 	<ul style="list-style-type: none"> • Extensive and in-depth case studies required to cover range of conditions • Variability among state agencies related to cost and data collection • Learning curve with any new models may delay their use and acceptance 	<ul style="list-style-type: none"> • Variability among state agencies • State priorities differ from Federal priorities, potentially influencing assessment of needs • Places analysis burden on state DOTs – difficult to manage at national scale • One time application only – not conducive to “what if” analysis

For the purposes of comparison, Tables 2.3 and 2.4 qualitatively summarize the level of effort required (including staff time and resources required) and the likely reliability of the estimates resulting from each methodology. The qualitative ratings for each methodology – characterized as “Low,” “Moderate,” or “High” – were assessed relative to one another based on the research team’s experience in conducting previous national-level needs assessments.

Table 3.3 Expected Level of Effort Required

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology
Method 1: Analytic Tools	Moderate	High	Moderate	N/A
Method 2: Case Studies	High	High	High	Moderate
Method 3: Hybrid	Moderate to High	High	Moderate to High	Moderate
Method 4: State-Assessed	High	High	High	High

Table 3.4 Expected Reliability of Estimates

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology
Method 1: Analytic Tools	High	Moderate	High	N/A
Method 2: Case Studies	Moderate	Moderate	Moderate	Moderate
Method 3: Hybrid	High	High	High	Moderate
Method 4: State-Assessed	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate

3.3 METHODOLOGY RECOMMENDATION AND IMPLICATIONS

All of the methodologies have strengths and weaknesses. They are more or less appropriate to each of the four program components in terms of their ability to estimate the needs associated with the relevant program strategies. Data, both quantity and quality, and analytics will be an issue no matter which method is selected. In addition, some options require work at the state level and effort by each state DOT, while others can be conducted at the national level.

Hybrid Method

Taking all of the factors into consideration, the research team recommends Method 3, a hybrid of Methods 1 and 2. It is applicable for estimating the needs of three of the four program components: Preserving our Transportation System, Operating Our Assets Efficiently, and Growing our Transportation

Infrastructure. Method 3 utilizes existing analytic models such as HERS and NBIAS, to estimate IHS needs. While there are some concerns about data adequacy and potential complexity, these analytic models are the best tools available and have been shown to yield plausible results within the stated limits of their applicability. Utilizing the hybrid method to supplement the models with case studies will address the perceived limitations in the analytic models. These analytic models can be strengthened and updated with observed information on costs, effectiveness, outcomes, and feasibility constraints that would be collected through case studies and applied to the output from the analytic models. One concern, potentially significant, is a tendency to undervalue the benefits of and the need to replace pavement that is fully deteriorated.

Special Issue: Harnessing Technology to Improve our System

The fourth program area will require its own tailored approach. With inherent uncertainty about new and improved technologies that may emerge over the coming decades, estimating the likely investment needs of harnessing technology will require additional understanding and insights into the leading candidates for technological advancements for developing, deploying, and managing IHS elements. An appropriate early task for the IHS investment needs study team will be designing the study needs/investment approach for harnessing technology. Recommended elements for that method design are described in the following section.

4.0 Proposed Work Plan

Taking the IHS study approaches and methodologies embodied in this proposed work plan and translating them into a detailed study of IHS needs will be the responsibility of a future research team. The purpose of this section is to provide the best possible understanding of how the approaches laid out in this report might be put into action. It lays out the research team’s recommendations about actions that should be taken to accomplish the steps of a major study of the 3R, 4R, and new capacity needs of the IHS.

4.1 STEPS NEEDED TO IMPLEMENT A WORK PLAN

Setting Performance Measures and Targets

Table A.2 in the Appendix describes the applications of the four methodologies to each of the four program areas. In each case, it is recommended that a performance target is set for each program area – network wide or for a specific component of the IHS itself (such as rural or urban, or based on overall traffic or truck traffic, etc.). The following steps should be considered for accomplishing this portion of the study:

- Convene an expert panel of researchers, academics, and DOT practitioners to guide the establishment of the performance management framework. The framework would include plausible goals and alternatives sets of measures and targets for consideration and adoption by the study team. The measures and targets should be complementary to the methodology and available data and consistent with the measures and targets adopted by FHWA and the state DOTs pursuant to MAP-21. The panel would need to:
 - Review and supplement MAP-21 goals where needed;
 - Review and supplement MAP-21 measures where needed;
 - Review state-determined targets and determine process necessary to set national targets for use in the study;
 - Determine what variations, particularly in target levels that may reflect alternative national goals, should be considered.

Case Study Approach

The recommended Method 3 - hybrid approach -- requires representative segments of the Interstate to be selected for case study analysis. The case study analysis is to provide a “check” of the models and address any areas outside the model variables (such as pavement reconstruction needs). As the case study

approach represents a departure from the historic use of national models, the following steps are noted:

- Determine the number of segments and types of segments needed for the case studies to address the issues raised by the potential limitations of the models.;
- Design the case study process to include:
 - Exploration of any missing relationships;
 - Methods for probing the real world needs-based relationships;
 - Collection of consistent information across case studies that describe those relationships;
 - Exploration of commonalities across the individual case studies; and
 - Incorporation of information gleaned from the case studies into (or added onto) the analytic models.
- Determine how best to use the case study output to verify and supplement the results obtained through the models.

The framework developed for this study suggests that costs and benefits be estimated for each component separately and then combined.

The first phase of creating the cost estimates for each component is to estimate the mileage that require some defined type of improvement and then scale up according to the component share of the national system. To be sure that synergistic benefits are captured, a subsequent step should consider assumed investments in the other program components, be they operational or technological, which would then be fed back into the analysis to establish a new cost estimate. This may require several iterations to identify the appropriate mix of recommended improvements and cost by component.

In a similar manner, care must be taken to ensure that there are no systemic gaps or overlaps (for example, where to address limited auxiliary lane additions that are common during reconstruction projects, particularly in interchange areas, that add capacity and conceivably may be “counted” again under capacity expansion.)

One of the advantages of this modular approach is that it allows decision-makers to see the cost for the essential high priority improvements separately from the cost of more discretionary improvements. At the same time, recognizing the synergistic benefits to other program components it is essential to identify the most cost-effective mix. To guard against this, the study design needs to provide for iterative processes that can uncover synergistic benefits or gaps or overlaps.

How to Approach the “Harnessing Technology” Component

Today’s emerging technologies have the potential to have transformative impacts on how highway systems are developed and used and should be

considered in a major assessment of the future needs of the nation's IHS. A key challenge will be evaluating the impact of concepts that are not yet fully understood or known.

Clearly, there is no foolproof, accurate way to do that, but there are approaches that can be developed. Some steps to consider include:

- Scenario planning, drawing inferences from research on emerging technologies that are likely to apply to the IHS, the potential implication of their deployment and the likely pace of deployment can be explored via scenario planning;
- Convening an expert panel or hosting workshops among technology experts in various categories that would have a measurable effect on IHS needs, costs and benefits across the future time horizon;
- Determining a reasoned estimate of need for technology deployment that is not specific to any particular technology but will provide a pool of resources for emerging technologies be build into the IHS cost estimate.

Need for a Scenario Planning Approach

It is strongly recommended that any work plan for the detailed study of the IHS include a scenario planning approach. Specific alternative goal mixes for the four recommended components of the IHS study should be identified as well as their application to various components of the IHS itself (such as rural or urban, or based on overall traffic or truck traffic, etc.) at given performance level targets and the outcomes of the various approaches evaluated and compared. Scenarios can be created for each of the four program components individually or for an overall future IHS by creating scenarios based on all various mixes of the four components.

Communications Plan

The cost of conducting a major IHS needs study is great, the effort in terms of time and staffing will be notable and the potential consequences of the study, if implemented, on the national transportation system significant. Consequently, it is important that the large, interested community of transportation planners, practitioners, and decision-makers are aware and kept apprised of the study, and most importantly, have *input* into the study.

It is recommended that the scope of the study include a communications plan to ensure that interested and affected participants or stakeholders, including groups whose views may conflict with program goals (such as capacity expansion), are engaged and provided with opportunities to provide input. This is not only consistent with the spirit of MAP-21 and initiatives among many states to enhance collaboration and transparency, it offers the opportunity to focus on how the points made by critics of the process can be elicited and addressed in the most effective and compelling manor.

4.2 DATA IMPLICATIONS OF THE PROPOSED APPROACH

No matter what methodology is used to conduct a major study of the 3R, 4R, and new capacity needs of the IHS, having good data is an essential element in producing a credible result. A question frequently raised about a reliance on models such as HERS and NBIAS, as the hybrid approach outlined in this report recommends, is whether the data available and used by these models are accurate enough to produce reliable resources. Based on the study team's analysis of and experience with the data used by HERS and NBIAS, particularly with the focus is on the IHS (as opposed to the entirety of the National Highway System), the data are deemed to be sufficient both in availability and reliability to support the use of these tools for the purpose at hand.

Highway Performance Monitoring System

The HPMS provides substantial data on the road network. While there are legitimate concerns about data quality and coverage, these data are fairly robust for the existing Interstate system, including pavement condition, system extent, traffic volumes, and other relevant data. Some of the most commonly cited concerns about these data include:

- **Consistency in measurement of basic pavement data.** While all states have long reported Internal Roughness Index (IRI) data to FHWA for HPMS, there are some concerns about the consistency of data collection protocols (single or bi-directional, which lane data are collected in, and other similar issues).
- **Availability of more robust pavement condition data.** New reporting requirements were implemented in 2012. These data are not required universally and there are significant inconsistencies in how these data are collected across states.
- **Tracking of previous investments.** HPMS provides only limited understanding of previously IHS work, tracking only when a given segment was last reconstructed.

Although concerns about HPMS data have hurt credibility of HERS needs assessments in the past, the recommended hybrid approach will incorporate case studies on sample segments to provide "reality checks" and opportunities to adjust the parameters and data used by HERS in ways that can improve the validity and credibility of the data.

National Bridge Inventory

The NBI data are used to feed the NBIAS. Compared to HPMS data, there is significant consistency in how these data are collected and reported. NBI is in the process of being updated to include element level data; currently condition data are collected at an aggregate level for deck, substructure, and superstructure. For the purposes of long-range planning, NBI data generally are

sufficient. Element level data will help remove some of the subjectivity from current bridge rating efforts by focusing reviews on specific elements, not broad groups of elements.

Data Related to New Systems and Technologies

Data related to established technologies such as ramp metering are very robust. Data related to new technology and systems (both transportation systems management and operations and construction-related traffic management strategies) are much more limited. Some case study examples and rules of thumb have been compiled by FHWA. However, the examples are context specific and do not cover the complete range of emerging technologies – much less the varying levels of state-specific applications, where costs would vary substantially depending on the current state of applications. The section of the work plan that addresses “Harnessing Technology” will need to address approaches for compensating for the limited data available for emerging technologies.

Data Issues if Additional Network is Evaluated

Should a study of the 3R, 4R, and new capacity needs of the IHS recommend expanding the study to include the NHS, there are additional data issues that would arise. Many of the data elements included in HPMS are universal for the NHS, but not for the NHS+ as expanded by MAP-21. Because some data items are only required for samples, the ability to credibly conduct the analysis may be compromised if the scope of the IHS analysis is expanded to include the NHS.

Data Conclusions

There are and will be data issues in a comprehensive study of IHS needs. Some of these issues may require the study team to come up with compensating approaches. However, the core data needed for the study have been collected for many years, the quality of the data has been analyzed many times, and these core data are sufficient to support an IHS study.

4.3 KEY PARTICIPANTS

The following factors should be considered when defining the roles and responsibilities of key participants in the study:

- The study must be collaborative. It needs to advance an understanding of the technical issues sufficiently while presenting politically realistic and sensitive findings. In order to do that, current and future owners, operators, and users of the system (including the private sector stakeholders) need to be included in the study process;

- The institutions that are the sources of data for the information needed for the study (State DOTs and AASHTO as well as FHWA) should be part of the process to facilitate access to their perspectives, data and expertise;
- The Transportation Research Board (TRB) represents a valuable neutral sponsor lead for the study (either using the NCHRP or Policy Studies vehicles) with contract research support that can tap the available expertise. It is suggested that a special blue ribbon panel of national experts willing to participate and who would be precluded from performing the study would be constituted as an oversight panel, supported by technical subgroups in each of the specialty areas.
- Considering that a robust institutional memory exists in the highway industry in applying the techniques involved in implementing the study, this should be tapped for efficiency and effectiveness of the study in order and to build on the lessons learned from past national needs assessments.

4.4 COST AND TIME

Without a fully developed project scope and work plan for a major 3R, 4R, and new capacity needs study of the IHS, it is difficult to accurately estimate the cost of such an undertaking. However, an estimate of what it will cost to conduct the study will be an important consideration when determining if the study is funded. For comparison purposes, the research team considered preparation of the biennial needs study for the *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* report to Congress (known as the C&P report).

The investment made by FHWA to support and conduct the C&P report has been in the range of \$1 to \$1.5 million per year, varying depending on the level of innovation from the previous cycles. The effort to produce the C&P report includes updating the HERS and NBIAS models, conducting a needs assessment using these models, adjusting and calibrating the output, and preparing the C&P Report. The C&P has a legislative mandate to be provided to the Congress on a two-year cycle. Generally, FHWA has been able to conduct the analytical elements and prepare the written drafts within that time. This time line is possible due to the high level of C&P report staff expertise at FHWA and because there are only a marginal number of changes made from edition to edition.

The range of \$2 to \$3 million and a two-year time period needed to complete the C&P report is used as a starting point to estimate the time and cost required to conduct this 4R, 3R, and new capacity needs of the IHS study using the hybrid approach recommended in this report. The hybrid approach will have a set of specific costs associated with its methodology, including a sequence of:

- Case studies;
- Initial modeling;
- Incorporating the case studies findings;

- Potentially adjusting model output; and
- Dealing with the non-modeled so-called “new technologies.”

If the analyses for the new study is constrained to the existing IHS only, it is reasonable that sufficient case studies could be conducted, their findings incorporated into model improvements, and the final modeling work executed in a 12-18 month period. If the scope of the new study expands beyond the IHS, it would be less likely that sufficient case studies and modeling changes could be accomplished in that time period, and the study period would likely extend to a 18-24 month period. As this is a new study with significant policy implications and one that will receive wide-spread policy exposure requiring extensive review, an additional 6 months needs to be added to the time required for the technical work.

The following provides a realistic breakdown of the likely timeline:

- Two to three months of work plan refinement (including panel confirmation of goals and desired alternative outcomes);
- Nine months to conduct a robust set of case studies;
- Followed by two months of model design/adaptation;
- Followed by six months of model simulations and preliminary report drafting; and.
- Before the report would be final, another six months will be needed for an extended review and feedback cycle both in industry and policy arenas.

Timeliness is critical in order to have meaningful results available on a schedule that supports potential decision-making regarding Federal highway system-related legislation. Any final study design should take the policy timeline into consideration, but it will be difficult to complete a credible study in less than 24 months. Even with the level of staff experience at FHWA in producing the C&P report and the typically small number of changes made in the report from one cycle to another, the time needed for the report to be reviewed and for the document to be cleared for publication has regularly delayed the release of the report by as much as six months. The authors of and panel for a national study of the 3R, 4R, and new capacity needs of the IHS should be mindful of this potential for delay when laying out the schedule for this study.

The estimated cost for conducting the study is based on the following considerations:

- Historic investments in model development, refinement, and application of \$2 to \$3 million for each C&P cycle. This study will supplement the existing modeling with conclusions derived from case study to address perceived weaknesses.

- In order to produce a credible study, a collaborative approach will be needed. Collaboration requires more time and adds expense. Further, the study design anticipates the inclusion of a communications plan.
- An expert panel should be convened and workshops possibly held to determine the assumptions to be used for harnessing technology.
- Case studies representing a broad cross-section of the nation's IHS will need to be conducted.
- Information gleaned through the case studies, expert panels, and collaborative efforts will create revised assumptions. The analytics and models will need to be adjusted and tested based on this work.

Using historic costs as a starting point (\$2 to \$3 million), recognizing the additional costs associated with conducting case studies (\$300,000 to \$600,000), adding a communications plan (\$50,000 to \$100,000), including support of an expert panel (\$50,000 to \$75,000) and recognizing that there will likely be other approach modifications that this study will require, the cost estimate to do this study is \$3 to 4 million.

The estimated timeline is very concentrated and achievement of the deadlines within such broad cost estimates assume that the study team will have the cooperation of the FHWA, and that there will be efficiencies in terms of both time and cost by being able to access FHWA's detailed assumptions, scenarios, and operational decisions. Additionally, being able to access the knowledge and judgments of FHWA staff will be very helpful.

In conclusion, this study is estimated to cost between \$3 to 4 million and require 24 to 30 months to complete.

5.0 Conclusion

The IHS provides the backbone of the national transportation system. However, what was once a premier system that stood as a symbol of American growth and economic vigor is showing its age. A major study of the 3R, 4R and new construction needs of the IHS is in order.

Though regular maintenance and reconstruction of the IHS has been conducted, that investment has not been sufficient to avoid the IHS falling into considerable functional and physical obsolescence. Traffic in many regions of the country has grown far more than was originally projected, particularly for commercial vehicles. At the same time, continued growth and development in many parts of the country – both automobile and commercial -- are straining existing capacity.

New technology provides a wide range of additional opportunities. For those technologies that are known today, the current gap between best practice and prevailing practice is significant; so just by advancing the norm from the state of the practice to the state of the art, large gains in efficiency and effectiveness might be realized. As new systems and technologies become available (some involving vehicle technology) higher levels of safety, operational and economic performance are likely to be gained.

Gaining an understanding of the costs and benefits of restoring the function and physical condition of the Interstate, addressing capacity shortfalls, and exploring the benefit of deploying new systems and technologies is critical to USDOT, AASHTO, TRB and ultimately to Congress in order to determine the level of investment the U.S. should make in the IHS.

A modular, performance based, scalable approach to an IHS study that relies on the analytic tools and models previously used by FHWA, primarily HERS and NBIAS, supplemented with case studies to make up for the perceived limitations contained in the analytic tools will provide decision-makers with the benefits, costs and trade off information needed to inform their decision as to the needed investment level to provide America with an IHS that is strong, vibrant, and is once again an economic engine for the U.S. economy.

A. Alternative Methodologies

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Table A.1 Methods for Estimating Required Investment in Program Components to Meet IHS Investment Needs

	METHOD 1. MODEL NEEDS WITH EXISTING ANALYTIC TOOLS	METHOD 2. CASE STUDY APPROACH TO DEVELOP SAMPLE SEGMENT COST ESTIMATES	METHOD 3. SUPPLEMENT ANALYTIC TOOLS WITH CASE STUDIES (HYBRID OF METHODS 1 AND 2)	METHOD 4. STATE ASSESSED MILEAGE COMBINED WITH CONSULTANT ASSESSED PROJECT TYPE AND COST
Overview	This established methodology for the assessment of the investment needs of the IHS relies on the use of existing analytic tools – previously used in FHWA studies, primarily the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS). To ensure the analysis covers the majority of the program components, these models have been supplemented by additional proven analytics such as the ITS Deployment Analysis System (IDAS) and the Transportation Operations Benefit Cost (TOPS-BC) Desk Reference	This methodology consists of developing cost estimates for sample segments of the IHS using a forensic/case study approach, looking in detail at rehabilitation/replacement cost on sample segments, and then applying the estimates on a system-wide scale. A national cost estimate would be based on expanding a representative sample of segments to estimate costs of and maintaining conditions and performance.	A hybrid of Methods 1 and 2, this approach would adjust and/or confirm the investment needs estimated by analytical tools (HERS, NBIAS, IDAS, etc.) with selected case studies as described in Method 2.	Using national cost estimates for a list of standard improvements in each program component, individual states would be asked to provide estimates of applicable IHS mileage. State estimates would then be aggregated for national total.
Overall Strengths	<ul style="list-style-type: none"> Well established methodology with considerable applications experience for estimating both preservation and capacity needs (used in AASHTO’s Bottom Line Series, the Conditions and Performance Report to Congress, and by the National Surface Transportation Policy and Revenue Study Commission) Most supporting data are available, reasonably up-to date, and reliable 	<ul style="list-style-type: none"> Can include selection of segments likely to drive significant portion of IHS investment needs Creates detailed “stories” of IHS needs that increase transparency and potential acceptance of findings 	<ul style="list-style-type: none"> Case study information could be used to adjust the parameters and data used by the existing models. Helps to improve understanding and credibility of the national needs assessments 	<ul style="list-style-type: none"> A simple solution that does not rely on models; addressing each program component Benefit of drawing from in-depth knowledge and expertise of state DOTs for enhanced credibility While standard improvement costs may not reflect individual state conditions on a segment by segment basis, it will provide a reasonable overall state and national cost estimate
Overall Weaknesses	<ul style="list-style-type: none"> Limited applicability to non-preservation and non-capacity needs estimation, Scale and complexity results in lack of transparency and impacts credibility (“black box” perception) Inability to clearly account for estimating replacement costs for facilities that have outlived their service life, unreliability of input for HPMS pavement data, and inflexibility in incorporating additional IHS costs aside from primary preservation assets Fails to account for staffing and maintenance costs of new systems and technologies 	<ul style="list-style-type: none"> Challenging to select and expand statistically valid representative sample of segments Extensive and in-depth case studies are necessary to cover the appropriate range of conditions to be able to scale up needs credibility Not suitable for estimating new IHS links – extensions and connections Time and resource requirements Variability among transportation agencies in how cost information as well as other data are collected and defined Not a widely accepted method for IHS needs estimation due to perception that no two states are identical in the factors that may drive an estimate of needs Fails to account for staffing and maintenance costs of new systems and technologies 	<ul style="list-style-type: none"> Extensive and in-depth case studies necessary to cover the appropriate range of conditions to be able to scale up IHS needs credibility Time and resource requirements Variability of cost data for major reconstruction and new construction depending on type of project, geology, etc. If new or enhanced models need to be developed to address the analytical issues, issues associated with data and the learning curve associated with any new set of algorithms could delay their use and acceptance Fails to account for staffing and maintenance costs of new systems and technologies 	<ul style="list-style-type: none"> Planning horizons and other key analysis considerations such as performance targets are unlikely to be synchronized across states, requiring significant analysis and guesswork to establish guidelines and adjust inputs accordingly State priorities differ from federal priorities, potentially influencing their assessment of needs Places analysis burden on state DOTs – difficult to manage and control at a national scale May be more difficult to create a range of costs by varying performance goals One time application only, not conducive to “what if” analysis; no tool developed that can be applied for future use Fails to account for staffing and maintenance costs of new systems and technologies

Table A.2 Applying the Methods to Program Areas

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology to Improve the IHS
METHOD 1. MODEL NEEDS WITH EXISTING ANALYTIC TOOLS				
Key Steps	1) Create performance target scenarios for pavement and bridge condition, 2) Use HERS to estimate pavement maintenance and replacement needs, 3) Use NBIAS to estimate bridge maintenance and replacement needs, 4) Conduct sensitivity testing to estimate impacts of assumptions, 5) Iterate with alternative performance targets, as appropriate	1) Create performance target scenarios for congestion, reliability, and safety, 2) Use HERS and NBIAS to estimate capacity needs, 3) Iteratively deploy the IDAS tool to conduct an analysis of the effects of aggressively deploying ITS and operations strategies on the IHS, 4) Conduct sensitivity testing to estimate impacts of assumptions, 5) Revise assumptions and select preferred scenario	1) Create performance target scenarios for congestion, reliability, connectivity, and economic development, 2) For expansions, use HERS and NBIAS to estimate capacity needs, 3) For extensions/connections, develop specific functional criteria to identify needed extensions of the IHS on a mileage basis, 4) Apply to model estimates 5) Conduct sensitivity testing to estimate impacts of assumptions, 6) Adjust the model-derived capacity needs to reflect public acceptance and/or feasibility constraints of capacity investments (such as impacts or affordability), 7) Revise assumptions and select preferred scenario	This method does not provide an effective estimate for this program area.
Notes	Limited ability to capture additional assets for preservation (drainage, lighting, signs, noise barriers) Questionable ability to capture full costs of major reconstruction	IDAS application requires data regarding current state-by-state level of Transportation Systems Management and Operations (TSM&O) applications		
Data Needs (& Sources)	Pavement condition (HPMS), Bridge condition (NBI), Cost estimates (HERS & NBIAS), Deterioration curves (HERS & NBIAS)	Travel demand forecasts, Benefits/costs of ITS and operations strategies (IDAS); State-by-state level of TSM&O applications	Travel demand forecasts, Capacity costs (HPMS & NBIAS)	n/a
Level of Effort	Moderate	High	Moderate	n/a
Likely Reliability of Estimates	High	Moderate, depending on number and strength of the case studies used	High	n/a
METHOD 2. CASE STUDY APPROACH TO DEVELOP SAMPLE SEGMENT COST ESTIMATES				
Key Steps	1) Identify representative sample segments for review (focusing on preservation needs), 2) Quantify segment needs, 3) Aggregate to IHS level, 4) Adjust based on performance targets	1) Identify representative sample segments for review (focusing on operational projects), 2) Quantify segment needs, 3) Aggregate to IHS level, 4) Adjust based on performance targets	1) Create performance target scenarios for congestion, reliability, connectivity, and economic development, 2) Identify representative sample segments for review (focusing on capacity projects), 3) Quantify segment costs, 4) Estimate IHS capacity expansion needs, 5) Apply costs to IHS network 6) Adjust the assumptions to reflect public acceptance and/or feasibility constraints of capacity investments (such as impacts or affordability), 7) Revise assumptions and select preferred scenario	1) Research and convene national expert panel on emerging technologies 2) Identify potential technologies, 3) Quantify installation costs, 4) Estimate potential extent of IHS network for upgrade, 5) Apply costs to IHS network 6) Estimate impact of technology implementation on reducing life-cycle costs to maintain conditions and improve performance (travel time, reliability, safety, environmental)
Notes	Each key step requires significant effort and assumptions	Each key step requires significant effort and assumptions, Process would need to be significantly tailored to address operational projects	Each key step requires significant effort and assumptions. For expansions of existing IHS segments as well as new IHS links (extensions and connections) it would be lend greater credibility if such improvements were already included in a statewide or regional transportation plans	Each key step requires significant assumptions
Data Needs (& Sources)	Detailed pavement and bridge condition data, Sufficient case studies and data to determine "representative" sample, Rehabilitation/replacement costs	System performance pre- and post-investment, Current level of TSM&O applications by state, Operational project costs	Capacity project-related unit costs, state and regional transportation plans	Technology costs, Prototype installations
Level of Effort	High	High	High	Moderate
Likely Reliability of Estimates	Moderate	Moderate	Moderate	Moderate

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology to Improve the IHS
METHOD 3. SUPPLEMENT ANALYTIC TOOLS WITH CASE STUDIES (HYBRID OF METHODS 1 AND 2)				
Key Steps	1) Create performance target scenarios for pavement and bridge condition, 2) Use HERS to estimate pavement maintenance and replacement needs, 3) Use NBIAS to estimate bridge maintenance and replacement needs, 4) Isolate sections of the system with extreme reconstruction need, 5) Adjust model-derived costs of reconstruction in HERS/NBIAS with observation-based cost estimates and/or feasibility constraints and add in needs associated with other assets (drainage, lighting, signs, noise barriers, etc.), 6) Revise assumptions and select preferred scenario	1) Create performance target scenarios for congestion, reliability, and safety, 2) Use HERS and NBIAS to estimate capacity needs, 3) Iteratively deploy the IDAS tool to conduct an analysis of the effects of aggressively deploying ITS and operations strategies on the IHS, 4) Adjust the model-derived costs/effectiveness of ITS and operations strategies using case study estimates, 5) Revise assumptions and select preferred scenario	1) Create performance target scenarios for congestion, reliability, connectivity, and economic development, 2) For expansions, use HERS and NBIAS to estimate capacity needs, 3) For extensions/connections, develop specific functional criteria to identify needed extensions of the IHS on a mileage basis, 4) Apply to model estimates 5) Conduct sensitivity testing to estimate impacts of assumptions, 6) Adjust the model-derived capacity needs to reflect public acceptance and/or feasibility constraints of capacity investments (such as impacts or affordability), 7) Revise assumptions and select preferred scenario	Use Method 2 exclusively 1) Research and convene national expert panel on emerging technologies 2) Identify potential technologies, 3) Quantify installation costs, 4) Estimate potential extent of IHS network for upgrade, 5) Adjust model costs and impact assumptions 6) Apply costs to IHS network, 7) Estimate impact of technology implementation on reducing life-cycle costs to maintain conditions and improve performance (travel time, reliability, safety, environmental)
Notes			For expansions of existing IHS segments as well as new IHS links (extensions, and connections) it would lend greater credibility if such improvements were already included in a statewide or regional transportation plan	Each key step requires significant assumptions
Data Needs (& Sources)	Pavement condition (HPMS), Bridge condition (NBI), Cost estimates (HERS & NBIAS), Deterioration curves (HERS & NBIAS), Rehabilitation/replacement costs, Compilation of case studies detailing rehabilitation/replacement costs	Travel demand forecasts, Benefits/costs of ITS and operations strategies (IDAS), Compilation of case studies detailing system performance pre- and post-investment and operational project costs	Travel demand forecasts, Capacity costs (HPMS & NBIAS), Compilation of case studies detailing capacity project costs and feasibility constraints, State and regional transportation plans	Technology costs
Level of Effort	High	High	High	Moderate but a lot of unknowns
Likely Reliability of Estimates	High	High	High	Moderate
METHOD 4. STATE ASSESSED MILEAGE COMBINED WITH CONSULTANT ASSESSED PROJECT TYPE AND COST				
Key Steps	1) Consultant develops a set of standard preservation-type project scopes and determines a national, average unit cost for each scope. 2) Create performance target scenarios for pavement and bridge conditions. 3) Survey states to determine how many miles on their IHS require each of the preservation-type improvements. 4) Aggregate investment needs to entire IHS based on performance targets	1) Survey states on historical IHS operational costs, anticipated future operational costs, and system performance, 2) Create performance target scenarios, 3) Develop set of operations-type project scopes and national, average unit cost for each scope. 4) Survey states to determine how many miles on their IHS require each of the operation-type improvements. 5) Aggregate investment needs to entire IHS based on conditions and performance targets	1_ Survey states expansion plans 2) Survey states on historical IHS expansion costs, anticipated future expansion costs, and system performance, 3) Develop link between investment levels and system performance, 4) Create performance target scenarios 5) Develop expansion –type scopes and national, average, costs unit for each scope. 6) Aggregate investment needs to entire IHS based on performance targets and anticipated expansion needs	1) Research and convene national expert panel on emerging systems and technologies (U.S. and international) and related impacts, 2) Survey states on historical technology adoption investments, anticipated future technology adoption investments, and system performance, 3) Survey states to determine how many miles on their IHS require each technology adoption, 4) Estimate impact of technology implementation on reducing life-cycle costs to maintain conditions and improve performance (travel time, reliability, safety, environmental) on state-by state Aggregate investment needs to entire IHS based on performance targets
Notes	Baseline performance measures will need to be developed and utilized where states do not have reliable tracking	As some states may not be fully pursuing operational approaches, may require more direction to them as to where the operational projects should be deployed	For expansions of existing IHS segments as well as new IHS links (extensions and connections) it would lend greater credibility if such improvements were already included in a statewide or regional transportation plan	Historical spending is poor indicator of future technology investment and historic spending may be an underinvestment of current technology
Data Needs (& Sources)	Preservation-type project scopes to determine most used and data on historic cost from multiple regions of the country to create a national average cost for each scopes (States will provide available data or draw from NBI and HPMS)	Historical operational expenditures (States will provide available data), Determine both most common and most effective/needed operations-type projects, Benefit/costs of ITS operations strategies (States can provide available data and case studies can be explored)	State and regional transportation plans –related mileage additions and ,historical capacity expenditures (States will provide available data), Performance levels (States will provide available data or congestion level), Case study analyses to determine economic relationships	Historical systems and technology adoption expenditures (States will provide available data), Performance levels (States will provide available data), Research on emerging technology

	Preserving the IHS	Operating the IHS Assets Efficiently	Growing the IHS	Harnessing Technology to Improve the IHS
Level of Effort	High. More effort for states than other methodologies	High. More effort for states	High. More effort for states	High. More effort for states
Likely Reliability of Estimates	Low to Moderate. Requires significant coordination with states and effectiveness will depend on how effective that coordination is	Low to Moderate. Requires significant coordination with states and effectiveness will depend on how effective that coordination is	Low to Moderate. Requires significant coordination with states and effectiveness will depend on how effective that coordination is	Low to Moderate. Requires significant coordination with states and effectiveness will depend on how effective that coordination is