PART IV

Afterword: A View to the Future

Introduction

The data and analyses presented in this report are based on tools and techniques that have been developed over many years (in some cases even predating this report series). This development history has produced models and data collection techniques that are fairly refined and have evolved over time to reflect changing priorities and the latest in surface transportation research to the extent possible. At the same time, there is considerable room for improvement in our understanding of the physical conditions and operational performance of our Nation's surface transportation infrastructure, and in our analyses of future investment in that infrastructure.

This afterword is intended to discuss the gap between our current state of knowledge and understanding and the type of information that would be necessary and desirable to greatly improve this understanding. The section highlights issues and challenges that Federal, State, and local governments face in measuring infrastructure conditions and performance and, in doing so, helps point out some of the important limitations of the analyses that are presented in this report. Since many of these issues are fundamental or long term in nature, much of the discussion presented below is carried over from the 2004 edition of this report.

A common theme running throughout this section is the importance of high-quality transportation data and the impact data quality has on the analytical capabilities of the models that are used in the production of this report. In this context, data quality has many dimensions, including reliability, geographic depth and scope, and appropriateness for the types of analyses being undertaken. Many of the limitations of the current methodologies described here and elsewhere can ultimately be traced to limitations imposed by the current data sources. In many cases, in order to make significant improvements to the analyses, changes or improvements in data collection would be required to support revised analytical procedures. However, while more and better data are always desirable from the analyst's perspective, any improvements in this area must be balanced against the additional costs of collecting such data. Since most of the data used in this report are supplied to the Federal government by State and local government entities, issues relating to the cost of data collection, intergovernmental relationships, and the role played by each level of government in managing surface transportation assets must also be considered in determining what types of data collection are appropriate.

Q&A

What research efforts does FHWA currently have underway concerning the data used to support the analyses in this report?

The Highway Performance Monitoring System (HPMS) is the primary data source for many of the highway characteristics, condition, and performance metrics shown in Chapters 2, 3, and 4. The HPMS sample data set is also the primary data input for the Highway Economic Requirements System (HERS), which is used to generate the analyses of future investment for this report (see Appendix A). FHWA is currently conducting a comprehensive reassessment of the entire HPMS data collection process, including data collection methodologies, reporting requirements, data definitions, and the requirements of data users.

Because of the close connections between HPMS and the C&P report, the reassessment is carefully considering many of the condition and performance measurement issues and potential analytical improvements discussed in this Afterword section, including pavement modeling, capacity analysis, safety analysis, and data coverage. FHWA is also working closely with the State suppliers of the HPMS data to determine the feasibility of collecting new or modified data in these and other areas, using regional workshops, Web meetings, and other outreach tools. FHWA has also opened a docket to provide information and receive feedback from the public on any proposed changes to HPMS, which can be accessed at http://dms.dot.gov.

The current schedule for the reassessment calls for its completion during the first half of 2007. Any changes to HPMS would begin to be implemented during the 2008 reporting year and would thus be reflected in the 2010 edition of the C&P report.

In addition to discussing data issues, this section examines a number of conceptual, analytical, and informational issues relating to the C&P report where significant opportunities for improvement exist. For many of these areas, similar issues arise for both transit and highways and bridges, though in somewhat different contexts. The issues discussed here are similar to those addressed earlier in this report, including the physical condition of the infrastructure; capacity, operations, and operational performance; safety and security; travel demand, revenue, and finance; and multimodal analysis. The afterword concludes with a discussion of the analytical approaches used in the report, including the scope and presentation of the report analyses, and discusses additional uses of the tools and techniques developed for the report for other policy analyses.

A number of question and answer (Q&A) boxes are also included in this section, describing ongoing research projects sponsored by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) aimed at addressing the issues raised here. Some of these research projects also help to keep existing procedures up to date with current research in the field. These projects are sponsored by the offices tasked with preparing the C&P report and are intended to directly affect the analyses and content of the report. It is important to note, however, that many other research activities sponsored by other organizational units within the U.S. Department of Transportation (DOT), including the Office of the Secretary of Transportation, relate to some of these same areas. Selected research activities of the OST Office of Economic and Strategic Analysis under the Assistant Secretary for Transportation Policy, the FHWA Office of Freight Management and Operations, and the FHWA Office of Interstate and Border Planning are identified in text boxes within this section.

In the discussion that follows, it is important to bear in mind that many conceivable and desirable improvements to the methodology may not always be practical because of either their complexity or unrealistic data requirements. In some cases, improving one part of the analytical procedures can cause complications in other areas, introducing their own uncertainty to the analysis. It should also be remembered that even a technically perfect analytical approach would always be inherently imprecise when forecasting long-term investment needs because future trends in transportation, technology, and the economy as a whole cannot be projected with certainty. At the same time, it is helpful to describe that ideal in order to ensure that future development work will bring us closer to that goal.

The analyses presented in the C&P report reflect the results of an aggressive program of research in recent years, aimed at improving the analytical capabilities of the underlying models. A number of such research projects initiated using discretionary research funds made available under the Transportation Equity Act for the 21st Century (TEA-21) are still ongoing and will produce enhancements to the models that will refine the analyses presented in future editions of the report. Since the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), new research efforts in this area have been significantly scaled back. Therefore, the implementation of many of the new concepts discussed in this section should be viewed as a long-term effort that would likely need to be phased in over an extended period of time.

While this afterword is intended to provide a fairly comprehensive discussion of these issues and reflect the Department's current thinking about them, it is not intended to be the last word on the subject. There are certainly other issues worthy of discussion and other potential solutions to some of the impediments to improved analysis that are identified here. Instead, the intent is to help frame the discussion and spur dialogue among the Department, stakeholders, and researchers in devising improvements to the analytical processes used in the production of this biennial report.

Conditions and Performance

While significant strides have been made over the last decade regarding our understanding of transportation system conditions and performance, there is considerable work yet to be done. The outstanding gaps in our knowledge include the measurement of conditions and performance, modeling conditions and performance in investment analysis, and understanding the relationships between condition and performance measures and transportation user costs.

System Condition

Highways and Bridges

The FHWA currently collects and uses data based on the International Roughness Index (IRI) as its primary indicator for pavement condition. This measure has certain advantages, such as being objectively measured and having a direct impact on users of the road. However, concerns have been raised about its sufficiency as an all-encompassing indicator of pavement distress, since it may not adequately reflect pavement structural problems that do not manifest themselves simply through roughness. Collecting other, complementary pavement condition measures could substantially improve our understanding of the true condition of highway pavements and their remaining useful service lives; such measures are already being utilized in many States.

Improved pavement condition data could also be used to update and improve our modeling of pavement deterioration over time resulting from traffic loads and environmental factors. There are concerns that models currently being used may not fully reflect modern pavement design. This is particularly important in light of ongoing efforts to increase the useful life of pavement improvements. However, any advances that could be made in terms of the precision of these models would depend on the availability of additional data to capture other distresses that are not currently being collected on a nationwide basis.

As discussed in Chapter 7, the investment scenarios estimated in this report are for capital expenditures only and do not include ongoing routine maintenance. However, both FHWA and State departments of transportation are paying increasing attention to preventive maintenance strategies as a means of extending the useful life of pavement improvements. To the extent that such strategies are successful, they can reduce the need for capital improvements to address pavement condition deficiencies, an effect that the investment models should account for where possible. At a minimum, the models ought to be able to distinguish between the effects of standard preventive maintenance activities (presumably already captured) and more aggressive preventive maintenance strategies. Optimally, they would be able to directly evaluate the benefits, costs, and trade-offs between preventive maintenance and capital improvements.

Condition measurement and modeling issues also exist for bridges. As discussed in Chapter 3 and Appendix B, bridge condition indicators and bridge rehabilitation and replacement investment analysis are based on data from the National Bridge Inventory (NBI). These data are derived from bridge inspections and are reported for different major bridge components. However, in many cases, the data in the NBI are aggregated from more detailed element-level data. Since the structural deterioration models used in the National Bridge Investment Analysis System (NBIAS) are employed at the element level, such element conditions must be inferred from the aggregated component data. This presents the obvious question of whether it might make sense to directly collect the element data and use them in NBIAS.

Another bridge data issue concerns the types of distresses that are currently being evaluated. As with pavement condition, other structural distresses exist (such as substructure deterioration attributable to scour or vulnerabilities to seismic events) that are not currently being modeled or measured directly. Questions

Q&A

What research projects do FHWA and FTA currently have underway to improve the modeling of conditions and performance?

Current FHWA research projects on conditions and performance include the following:

- **Pavement model improvements.** This multiyear effort is assessing the current methods used to model pavement deterioration in both HERS and in other tools used for highway costs allocation studies. It is also looking at the types of pavement data and pavement modeling procedures currently in use at State highway agencies and evaluating the adequacy of the pavement condition data currently collected by FHWA for improved pavement analysis. One goal of this project is the development of more sophisticated next-generation HERS, which would be targeted for use in the 2010 edition of the C&P report.
- **Safety model improvements.** The FHWA is examining recent research linking average speeds and other highway characteristics to crash rates and severity, as a step toward improving the estimation of the safety cost impacts of highway improvements.
- **Bridge model improvements.** The FHWA is working with State users of the Pontis bridge management software (from which NBIAS was developed) that have customized the model to their own needs. The particular focus is on changes that States may be making to the default deterioration and improvement models, which could assist FHWA in making comparable changes to NBIAS.

Current FTA research on conditions and performance includes the following:

- **Decay Model Improvements.** Beginning in 1999, FTA initiated a program to collect consistent transit condition data from across the country that are representative of the national experience. To date this research has yielded new asset decay relationships for bus and rail vehicles, related maintenance facilities, and stations. Condition assessment research is currently underway for train control, communications, and electrification systems, while analysis of guideway and track is pending.

of how such measurement should be done and the extent to which other measures might pick up such factors are part of the research agendas of the FHWA Offices of Policy, Infrastructure, and Research and Development.

Another bridge condition modeling issue relates to concerns about our aging infrastructure. As discussed in Chapter 3, a significant portion of our Nation's bridges fall into the 40- to 60-year age range and thus may be nearing the end of their anticipated design lives. However, the age of a bridge is not directly considered in the bridge condition modeling approach used by FHWA (which is based on bridge management systems used by a majority of States in the United States). Is this a glaring oversight, or is this a more accurate representation of bridge deterioration than conventional wisdom might suggest? The important, unknown factor is the impact that minor and major rehabilitation work can have on extending the useful life of bridges. Is it possible to postpone the ultimate replacement of bridges indefinitely through such timely investments and interventions, or do aging and loadings ultimately result in required replacements regardless? If so, what historical data are available to determine which bridges of a given age have received such treatments and which have not, and could these be incorporated into the models instead?

A final area for improving our understanding of pavement and bridge condition concerns the relationship between condition and the costs borne by highway users and transportation agencies. How do agencies respond to different levels of pavement and bridge distress in terms of routine maintenance or capital maintenance expenditures in order to keep their facilities in operable condition? What is the actual relationship between pavement or bridge deck condition and highway operating speeds? The impact of pavement roughness on vehicle operating costs has been documented in the past, but the studies are now more than two decades old; is new original research in this area warranted? Also, for bridges, one of the most significant impacts of deteriorated condition is that vehicle weight limitations may have to be imposed in order to maintain an acceptable margin of safety, potentially forcing some commercial vehicles to be diverted. Can such postings be quantitatively connected to bridge condition metrics? How should such potential user impacts be incorporated into our estimates of the cost savings associated with pavement and bridge preservation improvements?

The ultimate rationale underlying much of the Federal highway bridge inspection and improvement program is to facilitate early actions in order to minimize the likelihood of a catastrophic failure. While the probability of such failures is low, the cost of such events is extremely high. Could this be a factor in explaining why State and local governments might appear to be overinvesting in bridge maintenance and rehabilitation in some areas? If so, should our bridge modeling approach directly incorporate such risk analysis?

Transit

The FTA uses a numerical scale ranging from 1 to 5 to describe the condition of transit assets. This scale corresponds to the Present Serviceability Rating formerly used by the FHWA to evaluate pavement conditions.

The FTA uses the Transit Economic Requirements Model (TERM) to estimate transit asset conditions and the investment required to maintain and improve these conditions. TERM is composed of a database of transit assets and deterioration schedules that express asset conditions as a function of an asset's age, utilization rate, and maintenance history. TERM has five major categories—vehicles, stations, maintenance facilities, systems, and guideway. Deterioration schedules are estimated for more specific asset types within each major asset category.

Most of the condition data used to estimate the deterioration curves in TERM have been collected through on-site physical surveys. These on-site surveys were begun in the late 1990s, beginning with bus vehicles and continuing, through 2004, with rail vehicles, bus and rail maintenance facilities, and rail stations. Inspections of train control, communications, and electrification systems were begun in 2005 and are continuing in 2006. A methodology was developed for each inspection before it was conducted. In most cases, the assets modeled are composed of a more detailed set of assets, each of which are examined and rated in the surveys. TERM has over 50 estimated decay curves. The final asset condition rating for each asset is an average of the conditions of its subcomponents.

The deterioration curves in TERM were initially based on data collected by the Regional Transportation Authority of Northeastern Illinois and the Chicago Transit Authority in the 1990s and mid-1980s and, to a lesser extent, on data collected by the Metropolitan Commuter Rail Authority (Metra) and the suburban bus authority (Pace) at the same time. The guideway deterioration schedules in TERM are still based on this information. FTA is currently examining the alternative for developing new guideway deterioration schedules, including the use of data collected by agencies. Physical inspections of guideway (track and related structures) may disrupt agency operations and are dangerous to perform.

The FTA is in the process of adding an overage index to TERM's condition rating output, defined as the proportion of assets by replacement value exceeding their useful life. This overage index will provide a measure of the level of deferred investment needs.

Over the longer term, FTA will be examining the effect of betterments on asset replacements and the possibility of introducing technical obsolescence as an alternative to physical condition in TERM's replacement criteria.

Operational Performance

Highways

One of the most important limitations in our current approach to highway operational performance is that our key indicators of condition are modeled rather than being directly measured. The most salient impact that highway congestion has on operational performance is a decrease in operating speeds, thereby increasing the travel time costs borne by users. As discussed in Chapter 4, there are several different aspects of highway congestion, including severity (the magnitude of congestion at its worst), extent (the size of the area or number of people affected), and duration (the length of the congested period). The different performance measures reported in that chapter reflect some or all of these aspects to varying degrees. However, one characteristic they all share is that they are actually modeled on the basis of roadway characteristics and reported traffic volumes.

Ideally, travel delay would be measured directly on an ongoing basis over the complete highway network. While such direct measurement has been an abstract impossibility in the past, increasing deployment of intelligent transportation systems (ITS) infrastructure and collection of real-time traffic data on major freeways and arterials in large urban areas are making it possible to directly measure travel times at different times of day on these important routes. The FHWA is involved in efforts to archive these data for analysis, an effort that is being extended to an increasing number of metropolitan areas (see Chapter 15). This effort has also led to the development of two new performance indicators, the Buffer Index and the Planning Time Index, discussed in Chapter 4. FHWA is also using communications and geographic information systems technologies to measure system performance with truck speeds, as described in Chapter 14.

According to studies sponsored by FHWA and other groups, a significant portion of the delay experienced by travelers in the United States occurs at bottlenecks, where capacity and throughput are restricted relative to the adjacent roadways feeding into the bottleneck. This primarily occurs at major intersections and interchanges and at "lane drop" locations where the number of through lanes is reduced. Addressing these chokepoints is one of the most difficult challenges faced by transportation planners. However, current methods for modeling performance do not expressly take into account the operational characteristics associated with bottlenecks, and there is a great need for research into the data and methodologies that could be used to further our understanding in this area.

> The FHWA Office of Transportation Policy Studies is studying the impact of highway congestion on truck freight shipments. A recent report identified 14 types of freight bottlenecks that caused 240 million hours of delay and cost highway freight $8 billion in lost time in 2004. Urban Interstate interchange bottlenecks accounted for the largest portion of delay. The study is available at
>
> http://www.fhwa.dot.gov/policy/otps/bottlenecks/index.htm.
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> Following the initial assessment, the Transportation Policy Office has begun a follow-on study better identifying the causes and potential solutions for interchange bottlenecks. Work has also been initiated in the FHWA Office of Operations, in conjunction with State highway agencies, to identify locations of recurring congestion.

Among the most common locations for bottlenecks are major bridges, especially those over rivers in major metropolitan areas. Expanding the capacity of bridges is very expensive relative to adding lanes to roadways in the immediate vicinity. As a result, bridge structures often will have fewer lanes than immediately adjacent roadways, thus creating a bottleneck during peak travel periods. As long-lived components of the highway system, bridges may also have design features (such as lane widths or shoulders) that were appropriate for traffic conditions at the time they were first built, but do not work well at modern traffic levels. Such bridges are termed to be functionally obsolete (see Chapter 3).

Bridge functional issues, however, are not addressed very well in the current performance and investment modeling techniques. This results in large part from the distinct databases that are used for collecting highway and bridge information. Improving our understanding of bridge bottlenecks will require a means to link the highway and bridge functional information contained in the NBI and HPMS databases; FHWA has initiated efforts to do this.

Temporary losses of capacity that occur in work zones and under other conditions also cause bottlenecks. The HERS model now considers work zone delay in its benefit calculations. Improving our understanding of bottlenecks generally will also help improve our estimates of work-zone-related delay, but additional research is warranted in other features of work zones (such as their typical length, duration, and timing).

In measuring highway performance, it is also important to consider that there are many different causes and types of delay, with different implications and solutions. For example, travelers care not only about mean travel times on a given facility, but also about the reliability of those travel times. Most performance metrics are aimed at capturing the recurring congestion delay that travelers experience, but there is much less certainty about how to measure and account for improvements in reliability. The Buffer Index and the related Planning Time Index represent one attempt to measure reliability, but other possibilities have been suggested. FHWA's current investment analysis methodology attempts to address reliability by estimating incident-related delay (a common source of unreliability) distinct from recurring congestion delay, and valuing reductions in incident delay at a premium relative to reductions in regular travel time. Ideally, one would want to address reliability directly by forecasting reliability measures such as the Buffer and Planning Time Indexes as a function of traffic and roadway conditions, but there is currently no method available for making such a link.

Traffic control devices are another source of delay on highways, as motorists are impeded by signals and stop signs. The HERS model estimates this type of delay (referring to it as "zero volume delay"), but does so on the basis of relatively limited information about the operation of traffic signals on a given highway segment. Improving estimates of this type of delay would require substantial additional data about signalization.

One phenomenon that is frequently observed as highway segments become increasingly congested during peak periods is that travelers will adjust their schedules to avoid the worst part of rush hour. While this effect, known as peak spreading, helps limit the maximum amount of delay experienced by motorists, it also means that many of them are being forced to travel at times other than those that they would prefer. For example, a worker who would ideally like to work a 9-to-5 schedule may rise several hours earlier (or spectators may leave an event early) in order to "beat the traffic." The result is referred to as schedule delay. While this type of delay is difficult to measure, increases in peak capacity that accommodate more traffic can significantly reduce schedule delay. These reductions can be quite valuable to highway users, even if some traffic shifts from adjacent time periods such that peak hour delay is not reduced significantly. However, such impacts are not considered in the current investment and performance analysis methodology.

While the most obvious impacts of congestion are on traveler delay, it can also have an impact on vehicle operating costs. To some extent, these impacts are a result of the reduced average speeds caused by congestion. However, the constant speed changes associated with stop-and-go driving put additional stresses on vehicle components and fuel consumption. While the current methodology accounts for such impacts on signalized roadways, a more complete accounting for these impacts would also extend to stop-and-go conditions on unsignalized facilities and in work zones.

Transit

FTA's current modeling capabilities measure performance in terms of operating speed and vehicle occupancy rates. Investments to improve performance come from either investing in a faster transit mode or in adding new vehicles to an existing mode and thus simultaneously reducing vehicle crowding and increasing service frequency. TERM employs user cost elasticities to estimate the additional ridership that is generated by service improvements, which reduce passengers' costs. At this point, TERM does not estimate how asset conditions affect transit performance in terms of its reliability or safety performance.

FTA will be examining the possibility of using service interruptions as a measure of transit performance, provided data on service interruptions more detailed than reported to the National Transit Database (NTD) can be collected from a sample of transit operators.

Safety

Safety is another key aspect of transportation system performance, and Chapter 5 presents data on various safety indicators. In the context of surface transportation infrastructure investment, there are many areas in which we need to improve our understanding of the potential impacts of highway investment on highway safety.

The first challenge lies in linking crashes to transportation infrastructure characteristics. Motor vehicle crashes and their severity result from many factors, including driver behavior, vehicle equipment and condition, and weather conditions, in addition to infrastructure-related factors. As a result, it can be difficult to fully assign the proper responsibility for crashes to the infrastructure itself, and thus to properly model the impact of infrastructure improvements on safety outcomes.

> FHWA is working with the Transportation Research Board to develop the Highway Safety Manual (HSM). The purpose of the HSM will be to provide factual information and tools in a useful form to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of their safety consequences. The emphasis of the HSM will be on the development of quantitative tools. Two software programs to support the HSM analysis include the Interactive Highway Safety Design Model (IHSDM) and SafetyAnalyst. The HSM is intended to serve the same role for safety analysis that the Highway Capacity Manual (HCM) serves for traffic operational analysis, and will provide a major opportunity for advancing the state of the practice in highway safety.

The process of linking infrastructure to safety outcomes would be improved by more precise crash location data. While extensive data are available on crashes involving fatalities, less information is available on injuries and property-damage-only crashes at a disaggregate level. As a result, the models have been unable to account for changes in the number of injuries or fatalities per crash on different types of roadways (such as different functional classes) over time.

A related issue is the impact of changes in average speeds on crash probability and crash severity. While the internal safety models used by HERS estimate crash rates on different types of roads, implicitly accounting for the former to some degree, no linkage is made to the latter. As a result, the model may tend to overstate the safety impacts of improving highway speeds on major urban freeways and arterials to some degree, as any increases in fatality or injury probabilities per crash are not captured.

Finally, HERS and NBIAS are designed to model the effects of routine capital investments for highway and bridge preservation and capacity improvements and seek to incorporate the safety impacts of those routine improvements. The models do not address capital investments for system enhancements, including targeted safety enhancements (such as median barriers, improved merge areas, and additional turn lanes). Traffic control upgrades are also frequently driven by safety concerns, particularly on lower volume roads. Directly modeling national investment needs for these types of improvements would require an entirely new approach, including the collection of additional or supplemental data and the development of new safety capital investment tools.

As previously mentioned, FTA's modeling process does not estimate how investment in transit affects safety. As with highways, this type of analysis would require linking specific transit incidents, injuries, and fatalities to the physical condition of specific transit infrastructure (e.g., a rail line segment). To do so would require agencies to report safety incident data at this level of detail, a change that would entail a significant increase to current NTD reporting requirements. Moreover, at this point it is not clear whether the expense of undertaking this additional work would prove worthwhile. Transit has a very good safety record and is, in general, a very safe mode of transportation. However, any increases in asset costs that result from safety improvements will be included in the investment scenario estimates as information on actual asset costs is collected. Costs estimated by inflating cost data gathered in earlier years would not necessarily reflect cost increases stemming from asset improvements.

Environmental Impacts

As noted elsewhere in this report, one feature of transportation system usage is that it can have impacts on non-users of the system. These effects are referred to as externalities. To the extent that the level of such impacts is affected by transportation investment, they should be captured in benefit-cost analyses of that investment.

The current highway investment methodology used by FHWA attempts to account for one of the most obvious externalities associated with highway investment and use, namely the effects of increases or reductions in vehicle emissions on the environment. The current methodology used in the HERS model to estimate such emissions is based on the latest methods used by the Environmental Protection Agency (see Appendix A of the 2002 C&P report for a more thorough discussion). Improvements that reduce emissions (such as by fostering more efficient engine operation) can produce environmental benefits, while those that might increase emissions (such as through additional highway usage) would produce environmental "disbenefits." Future changes in vehicle and fuel technologies and regulations can also have a significant impact on emissions rates, and these factors are reflected in the estimates produced by HERS.

Translating emissions levels into emissions costs for use in BCA, however, is a more challenging step, as it requires linking emissions, ambient air quality, the adverse impacts of poor air quality, and the economic cost of those impacts. Some of these relationships can be complex and highly nonlinear. A comprehensive analysis of these linkages would require significant information about current air quality conditions and other emission sources by locality, adding a high degree of complexity to the modeling process. At a minimum, however, it is prudent to stay abreast of ongoing research in this area to ensure that the emissions cost estimates for individual pollutants that are employed in HERS reflect the best information possible.

While vehicle emissions are one type of environmental externality, other impacts could potentially be similarly modeled, such as the noise caused by highway and rail traffic. Such efforts would require two key types of inputs. The first would be empirical estimates of the magnitude of such costs, related to the variables used or modeled in HERS (such as traffic levels by vehicle class). Second, noise impacts are very localized, applying only to the immediate vicinity of the roadway. Thus, modeling these effects would require more data on development densities (by type of activity) adjacent to roadways than are currently available. Similar issues would apply to other environmental externalities, such as water quality, climate change, and biodiversity.

TERM considers the social benefits of noise and emission reduction that result when travel is switched from automobile to transit in its benefit-cost analysis.

Two final issues in this area concern the battery of Federal and State laws and regulations relating to transportation investment and the environment. The first issue concerns the cost of making improvements. Rather than taking the negative environmental impacts of transportation investment as given, the laws and regulations require that these effects be mitigated to some degree. Such mitigation activities can add significantly to the costs of transportation system improvements, especially those extending beyond the current footprint of system facilities. The challenge is to understand what these costs are for typical projects of different types on different classes of facilities and to ensure that the improvement cost estimates fully reflect these mitigation costs.

A second issue concerns transportation investment in non-attainment and maintenance areas (i.e., regions that do not [or did not] meet the National Ambient Air Quality Standards). In regions that have been so designated, transportation investment projects must conform to plans for improving air quality. Some of the improvements modeled in HERS and NBIAS, while cost-beneficial on economic grounds, may not be feasible on environmental policy grounds. In general, the investment scenarios in this report do not take into account Federal or State policies that could restrict certain types of improvements in specific locations, nor is it clear that they should do so, given the way in which the scenarios are defined.

Transportation Supply and Demand

At its core, transportation investment analysis involves balancing the demand for transportation services with the supply of those services. It is thus important that both sides of this equation be modeled with as much detail as possible within the constraints of the analysis. Some of the key subjects of concern in this area include understanding the costs of supplying transportation capacity, the impact of operations improvements on increasing effective capacity, refining the modeling of transportation demand, and the link between investment needs and financing.

Capacity

Capital improvements for increasing highway capacity can take many forms, with widely varying costs and complexity. The most straightforward involve adding through travel lanes within the existing footprint of the facility (such as in the median of a multilane freeway) or using other right of way that has previously been reserved for that purpose. In other cases, however, the options for widening an existing roadway may be constrained by terrain, environmental considerations, existing roadway design factors, dense development immediately adjacent to the roadway, or other factors. Under such circumstances, adding capacity may require more extreme and costly measures, including new parallel facilities or bypasses, tunneling, double-decking, fixed guideway transit facilities, the purchase of very expensive right of way, the reconstruction of existing overpasses, or some combination thereof.

The current approach used by FHWA to estimate capacity expansion needs under constrained circumstances is to assume that the capacity equivalent of additional lanes could be added to the corridor in which the existing facility is located, but at much higher cost than under ordinary circumstances. The estimated per-lane-mile costs of such lane equivalents are based on estimates of the cost of the extreme measures described above. These higher costs help to capture in part the cost of major highway capacity expansion projects and are thus reflected in the national investment scenario estimates. However, the higher cost of such improvements (referred to in HERS as high cost lanes) also makes them less attractive from a benefit-cost standpoint, making them somewhat less likely to be implemented in the model than other improvements.

While the procedure of high-cost-lane equivalents helps to address the question of investment needs for major capacity expansion, it does so based on very limited data. The determination of whether additional lane equivalents would be added at high or normal cost is based solely on the widening feasibility data item coded by States in HPMS. There are concerns that this single variable may not be fully capturing all the information used by a highway agency in determining whether to undertake a major, high-cost capacity expansion project. If additional data were available, they could potentially be used to improve our modeling of such improvements. FHWA is exploring ways to improve the quality of this information as part of its HPMS reassessment.

Another class of highway capacity improvements includes functional improvements to freeway interchanges. In many locations, severe recurring congestion problems can be attributed to interchange deficiencies, rather than mainline capacity deficiencies. These bottlenecks may result from severe volume/capacity imbalances, in particular connecting ramps at interchanges (which, when extreme, can affect traffic in the through travel lanes) or they can be caused by other operational issues such as interchange spacing, inadequate merge areas, or weaving problems.

These bottlenecks generally occur at points where capacity becomes restricted (such as a lane drop on a major urban freeway) or where a functional issue (such as significant levels of intersecting, merging, or weaving traffic) serves to reduce the effective vehicle-carrying capacity of the road. Bottlenecks may also be associated with major intersections, bridges, or tunnels in large urbanized areas.

Untangling these bottlenecks often requires extremely complicated and costly investments. Solutions may also involve operations enhancements in addition to construction. Interchange designs are also becoming increasingly complex in some cases in order to accommodate high occupancy vehicle (HOV) or other special purpose lanes. States have indicated that interchange improvements represent a growing share of their overall highway capital expenditures.

The challenge for the C&P report is to ensure that the capacity issues that arise at interchanges and other bottlenecks are adequately captured in the investment modeling process. Improving our capabilities in this area could involve upgrades to existing models and/or the creation of a new analytical tool to handle these types of investments. FHWA is also exploring the possibility of collecting interchange performance and capacity data as part of its HPMS reassessment, which would be necessary to support any new modeling techniques.

Another limitation of the current approach to modeling highway capacity improvements is that potential investments for new roads and upgrades of existing roads may not be fully captured. To some extent, as described above, the high-cost-lane equivalents feature is intended to capture new parallel routes in the same corridor (though modeled as an expansion of an existing facility). Given the relatively complete nature of the highway network in the United States, this makes a certain degree of logical sense—since few new roads are being built into undeveloped frontier areas at this point in the 21st Century, most new roads effectively substitute for existing roads to a certain degree. However, the new capacity in the model is assumed to be of the same functional class as the existing route, which may not be the case. Instead, new roads (at least those justified on the basis of capacity needs) are often built to higher standards (such as limiting access). Further, in the real world, capacity expansion of existing roads often takes the form of functional upgrades in addition to adding lanes, but such upgrades are not directly modeled in HERS. Thus, while the current procedures are intended to reflect such investments indirectly, a more refined approach (likely requiring additional data) would be possible.

Transit system expansion needs are currently driven by two variables—operating speeds and vehicle occupancy rates. A formula is uniformly applied to all systems to determine which are in need of performance-enhancing investments, i.e., they have speeds below and occupancy rates above certain threshold levels. Passenger waiting times are implicitly included in these performance measurements. No information is collected on passenger ease of access, the cosmetic appearance of the vehicles, or the comfort of the ride. This type of information is difficult to quantify and so is not explicitly considered.

Another transit capacity issue is referred to as core capacity. In urban areas with rail systems, investment in new capacity often takes the form of extensions to or branches from existing lines. As the system expands and ridership grows over time, however, the central portions of the system (often the first parts built) may become saturated with trains and riders. When this occurs, improving the capacity of the overall system may require new capacity improvements in this central core. Such improvements can also affect the operation of the entire rail system, beyond the locations of the actual investment, and thus offer significant benefits to riders. However, since the core sections of these systems are generally found in the densely developed central areas of major cities, expanding capacity in these areas can also be enormously expensive. The challenge faced by FTA is to ensure that the methodology used by TERM adequately reflects such improvements in its estimates of transit capacity investment needs and impacts.

An ongoing challenge faced by both FTA and FHWA is to ensure that the unit costs of various types of transportation investments used as inputs to the models fully reflect the current cost of building and constructing those improvements. The agencies currently do this by periodically revisiting the source data used to generate these unit costs and revising them accordingly. A trickier issue, however, is whether these unit costs will be stable (in inflation-adjusted terms) in the future. The key variable is the development and adoption of new technologies. Some technologies (such as longer-lived pavements or improved construction techniques) could make future infrastructure investments relatively less expensive, while others (such as more accessible buses using cleaner fuels) could make them more expensive than at the present time. While such impacts are difficult to predict, they do add to the uncertainty surrounding the estimates of future investment needs. Chapter 10 includes analyses of the impact that a significant increase in construction costs would have on the investment scenario estimates.

Operations

As described in Appendix A and elsewhere in this report, the HERS model considers the impact of operations strategies and ITS deployment on highway system performance and potential future investment. The procedure is implemented in the form of exogenously specified scenarios for future deployments, which in turn impact the HERS calculations on the effects of different highway improvements.

Ideally, one would want to extend this feature by bringing operations inside the benefit-cost analysis, considering each strategy as an improvement alternative in addition to those already specified in HERS. However, such an effort would raise several issues. First, many operations strategies and deployments are implemented not as alternatives to traditional highway investment, but rather in conjunction with them. For example, almost all freeway reconstruction and expansion projects in large urbanized areas today include new or upgraded ITS deployment as part of the overall project (typically, some ITS deployments require modifications to the existing infrastructure, which can be made more cost effectively when major construction is already underway). Would it make more sense to assume that this trend will continue in the future and to "build in" the costs and impacts of such investment into the existing improvements analyses?

Another issue concerns the need to capture the full lifecycle costs of ITS infrastructure. Much of this infrastructure is based on electronic technology that has a shorter physical or useful life than traditional highway improvements, a fact that needs to be factored into the cost estimates of such deployments. Replacing or upgrading these systems may also present challenges or costs that do not occur during the initial deployment. The ITS technologies may require increased operating and maintenance costs to be effective, which would need to be considered in a benefit-cost analysis.

Another challenge to incorporating operations strategies more directly into the analysis is that some of these strategies are not capital investments at all, but rather programs that can be labor intensive (such as on-call service patrols). Analyzing such programs as direct alternatives to capital investment would require a shift away from the traditional focus of the report on capital investment needs only and thus raises issues similar to those associated with preventive maintenance expenditures.

Finally, the modeling of operations and ITS investment depends on collecting consistent and reasonably complete data on the current extent and location of such deployments. While several such data items are currently collected through HPMS, the reporting of these data has not been sufficient for modeling purposes, requiring them to be supplemented by other data such as FHWA's ITS Deployment Tracking System. FHWA is currently examining what the best approach might be for collecting these data in the future. The Real-Time System Management Information Program referenced in Chapter 15 may also provide an avenue for the collection of ITS deployment information.

At this point, TERM does not consider the impact of ITS on transit system performance. A measurable link between ITS deployment by transit systems and their performance has not been established, and data on ITS deployment by transit systems are not collected.

Travel Demand

Some of the most important inputs and procedures used in the transportation investment analyses found in the C&P report concern the modeling of current and future travel demand. As noted in Chapter 10, different assumptions about future travel growth can have significant impacts on the investment scenario estimates for both highways and transit. Improving this portion of the analysis would require more precise forecasts of future travel growth used in the models, as well as upgrades to the internal procedures used to adjust travel demand in response to changes in the performance of the system and the fees charged to users of the system. However, opportunities to improve on forecasts that are done at the metropolitan planning organization (MPO) and State levels may be limited, especially when considering the uncertainty inherent in any projections using a 20-year time horizon.

Travel Forecasts

The sources of the highway and transit travel growth forecasts used in the HERS and TERM models are described in Appendices A and C. These sources are very different, with their own strengths and weaknesses. For highway forecasts, the HPMS sample data used in HERS include forecasts of future traffic levels for each highway segment in the database, as well as base year traffic volumes. Having these forecasts (supplied by the States) for each section is an important advantage of the HPMS dataset.

Obviously, improving the accuracy of these forecasts would improve the quality of the analysis produced by HERS. It is important to understand, however, what "accuracy" means in this context. A critical assumption made in the HERS logic regarding these forecasts is that they reflect a constant "generalized price" to users. Thus, an "accurate" forecast input to HERS would be one that correctly reflects the amount of travel that would occur at a constant price; it does not mean that the forecasts accurately predict actual traffic volumes in the forecast year, which depends on improvements that may be made (or not made) in the intervening years.

One issue with this approach concerns the definition of the "price" that is assumed to be constant in the forecasts. Is it based on maintaining level of service (as reflected in user costs), or is it based on all costs paid by users (including user fees)? The current assumption in HERS is that it is the former. This question is particularly relevant in light of the new procedures in HERS allowing it to simulate changes in user fees through tax surcharges or congestion-based tolls.

As noted in Chapter 10, the constant price assumption regarding the HPMS forecasts seems to be reasonable in the aggregate, though it may not be so for individual sections. This could be improved by having information on the assumed future performance level associated with each of the section forecasts. This information could be used in HERS to more accurately specify the baseline traffic volume forecasts, which would then be adjusted endogenously within the model.

A separate but related issue regarding the baseline forecasts used in HERS concerns truck volumes and traffic shares. While the HPMS data include current estimates of truck volume shares and current and future estimates of total traffic volumes, there is no estimate in the data for future truck shares. If freight and passenger traffic grow at differing rates, however, then truck shares will be changing over time. The 2004 C&P report included a sensitivity analysis based on alternative estimates of truck volume growth from FHWA's Freight Analysis Framework (FAF). However, these forecasts rely on data that are produced only every 5 years, which limits the update cycle for them (the second generation of the FAF is currently under development). This is why no similar analysis is included in this report. Another significant issue is that the forecasts themselves may not be based on a constant price of travel for truck operators and would thus require additional assumptions about the future cost of travel in order for them to be most appropriately included in the baseline HERS analysis.

Unlike HPMS, the NTD data reported to FTA by transit operators do not include projections of future transit travel growth. Instead (as described in Appendix C), the forecasts used in TERM are derived from forecasts made by MPOs as part of their overall transportation planning process. These planning documents provide the only widely available source of transit ridership forecasts available at the local level. TERM uses the most recent passenger miles traveled (PMT) projections (in most cases 2002) available from a sample of 92 of the Nation's MPOs, including those from the nation's 33 largest metropolitan areas. These are the most comprehensive projections of transit travel growth available. Projected passenger trips or PMT estimated as a function of projected vehicles miles traveled (VMT) were used in lieu of projected PMT when the latter was unavailable. Transit travel growth rates for the urbanized areas for which transit travel projections were either unavailable or not collected were assumed to be equal to the average growth rate for an urban area of equivalent size for the FTA region in which that metropolitan area is located.

There are several shortcomings of this methodology. First, the regions covered by the PMT forecasts may not correspond precisely to the service areas of the transit operators to whom they are being applied, particularly in regions with multiple operators. Second, PMT forecasts may also be for passenger trips, rather than passenger miles as used by the model. Historically, movements in the number of passenger trips and passenger miles have been virtually identical, so this is not a major concern unless a particular area has a marked change in average trip length. Third, PMT is forecast as a function of VMT for areas where neither PMT nor passenger trips are available. While a strong correlation is found to exist between PMT and VMT, the fact that this estimation does not account for the fact that transit and travel by private vehicle are substitutes is of theoretical concern. Finally, while the PMT forecasts come from a rigorous and documented process, the long-range plans produced by MPOs are required to be constrained by both projected fiscal resources and the need to maintain conformity with air quality standards. As a result, they may not include all of the improvements that would be made in an unconstrained environment (which is desirable as a baseline for investment scenario analysis).

Demand Analysis

In the HERS model, the highway travel forecast inputs are adjusted endogenously in response to changes in estimated user costs on each section (see Appendix A). While these demand elasticity procedures add considerably to the quality of the analysis, they are applied to all traffic on the section on an equal basis. Disaggregating travel demand within the model could thus improve the precision of the analysis, as well as furthering the analysis of other policy options aimed at regulating travel demand.

One good candidate for disaggregation would be demand by time of day. Disaggregating by time of day would allow a better calculation of peak period travel delay and would correspond more closely with the peak/off-peak capacity calculations that are already employed in HERS. The model would be able to capture the effects of trip time shifting between peak and off-peak periods in response to relative changes in travel times in the two periods and allow for different demand responses to changes in user costs within time periods (e.g., allowing for greater demand elasticity values in off-peak periods, where trips may be more discretionary).

Travel demand could also be disaggregated between different vehicle classes. In particular, truck freight movements are likely to have different demand characteristics than passenger auto traffic, making it sensible to disentangle them in the analysis. Doing so would also ensure that exogenous changes in the mix between trucks and cars (due to different baseline growth rates) do not inadvertently affect total estimated traffic volumes via changes in average user costs for all vehicles.

Q&A

What research projects does FHWA currently have underway to improve the modeling of transportation demand and address pricing issues?

The FHWA has an ongoing research program aimed at improving the analysis of travel demand within HERS. These projects are, to a large degree, sequential as earlier improvements set the stage for and enable later refinements and enhancements.

The next phase in this effort involves disaggregating travel demand in HERS by time of day. This will also require some accompanying modifications to the modeling of capacity and delay. As discussed in the accompanying text, properly analyzing the demand-related aspects of peak period congestion requires segmenting daily travel demand into peak and off-peak periods and accounting for any cross-price effects between the two periods. This will also allow for a more refined approach to the analysis of universal congestion pricing.

While demand disaggregation is thus desirable in its own right, there are potential drawbacks to such an approach. In particular, the additional segmentation of traffic volumes into different categories, each with its own demand characteristics, will increase the complexity of determining equilibrium traffic volumes exponentially. As a result, other compromises within the procedures could be required in order to keep the analysis tractable.

The analysis of travel demand in TERM is much more limited. The model does not have procedures for balancing supply and demand directly, as it does not calculate the price of travel to users. Instead, the travel growth forecasts are taken as given, with limited procedures for adjusting ridership in response to certain performance improvements; no adjustments are made to the forecasts for any improvements that may be foregone. The effect of performance improvements on users costs is reflected with a one-time increase in demand, i.e., transit ridership, based on elasticities estimated by empirical studies of ridership responses to increases in headways or speed.

Pricing Effects

This edition of the C&P report represents the first attempt at analyzing the impacts of alternative pricing mechanisms. However, there are many refinements that could be made to the analysis that is presented in Chapter 10, which is very limited in its present form. Time-of-day demand segmentation would allow for the analysis of optimal congestion pricing in different time periods, with time-varying tolls and peak shifting, but such an analysis would still be more illustrative than empirical. A realistic analysis would require much more detailed modeling of the actual transportation network, with spillovers and feedback effects between parallel and connecting segments (see the discussion of network effects later in this chapter). Refining the model along these lines would likely reduce the exaggerated impacts shown in Chapter 10.

Other potential refinements would expand the definition of optimal pricing in this context, beyond the current focus on travel delay. The analysis could address other externalities (such as environmental effects) that are currently unpriced. It could also be expanded to look at differential cost allocation schemes, which would require a greater degree of disaggregation between trucks and passenger vehicles than is presently found in the model.

The revenue effects of pricing are also discussed in the "Finance" section below, and more extensively in Part II and Chapter 10 of this report.

Options for analyzing pricing in TERM (i.e., fare policies) are very limited at the present time, since it does not explicitly model travel demand (as noted above). While a more comprehensive analysis of transit investment and its impacts would include this as an option (as with road pricing), the appropriateness of doing this type of analysis at the national level is perhaps more questionable. While encouraging efficient pricing is currently a policy of the FHWA, transit fare policymaking has traditionally been considered a local matter, with little or no Federal input because transit operating costs are generally not federally funded. Any efforts to include fare policy in the analysis would need to take this into account.

> The Office of Economic and Strategic Analysis under the Assistant Secretary for Transportation Policy at U.S. DOT is supporting research that attempts to provide quantitative estimates of some of the impact that widespread pricing could have on travel, congestion, and investments.
>
> More information on the activities of this office is available at http://ostpxweb.dot.gov/

Finance

As discussed in Part II and elsewhere, this report represents the first attempt to link estimates of future investment scenarios to the funding sources that would (or could) be used to pay for those improvements. The analysis is based on the imposition of user surcharges to cover any costs of increased investment under a given scenario, as such charges are presently the dominant revenue source for highway infrastructure improvements in the United States. Further refinements of the procedures used in this analysis could allow for such features as assigning different user surcharges to different vehicle classes.

The HERS revenue analysis does not account for the distortionary impact that tax-based revenue sources for transportation have on the economy (sometimes referred to as the social cost of public funds). Since the extent of this distortion varies for different types of tax mechanisms (such as property, sales, or fuel taxes), different mixes of revenue sources would have different implications in this regard.

One of the results discussed in Chapter 10 regarding the analysis of congestion pricing is the significant amount of revenue that is generated by the congestion tolls. Modifications to the current procedure would be needed to moderate these revenue impacts by allowing these revenues to offset other user fees or funding sources. Issues relating to congestion pricing are discussed in more detail in Part II of this report.

> The Office of Economic and Strategic Analysis under the Assistant Secretary for Transportation Policy at U.S. DOT is supporting research that examines the revenue-generating characteristics of different road tolling and pricing options and the effect of different allocation policies for such revenues.
>
> More information on the activities of this office is available at http://ostpxweb.dot.gov/

There is also room for improvement in the quality of the financial data collected by the Federal government. For example, data on local government highway revenues and expenditures are more limited and less timely than the data collected from States, which necessitates interim estimates that occasionally may diverge widely from final numbers. There are also limited data for lower-order highway functional systems, such as non-Federal-aid highways, and for transit operators in nonurbanized areas. Finally, there are limited data on private investment in surface transportation infrastructure. For example, local roads in residential or industrial areas are often funded by private developers, and local governments may require additional contributions toward improvements on nearby collectors and arterials as a condition of development. New freeway capacity is also being added in some areas under franchise agreements or public-private partnerships, a trend that is expected to continue in the future. However, the extent to which such expenditures would be captured in the current data depends largely on whether the actual expenditure was made by the private or government entity. Similar issues arise for public transportation services provided by private firms or organizations.

This type of analysis requires a means of forecasting expenditures by different levels of government over a multiyear period. Since Federal funding depends significantly on both Highway Trust Fund revenues and the program financing structure authorized by Congress, such forecasts are made only for the period covered by a legislative authorization. For this reason, no such projections were included in the 2004 edition of the C&P, which was based on data near the end of the TEA-21 authorization.

The second component of these projections involves forecasts of State and local expenditures. For the 1999 and 2002 reports, such forecasts were made based on an older modeling technique developed by FHWA. This raised concerns, however, over the assumptions about future State and local government behavior that are implicit in this approach. In particular, while transportation funding by State and local governments is influenced by economic conditions and system characteristics, it also depends on legislative actions (such as tax changes). In addition to the difficulty of projecting such funding, questions were raised as to whether it is proper for a Federal agency report to make such assumptions about the behavior of other governmental bodies. For this reason, the analysis in Chapter 8 of this report does not make any projections of State and local government spending (other than to assume that such expenditures would grow at the rate of inflation). Instead, it focuses solely on the effects of projected changes in Federal highway and transit spending under SAFETEA-LU.

Finally, it is implicit in all estimates of highway and transit investment and performance that a strong link exists between the two. However, we do not currently have the data to directly link highway improvements and costs on a given section to changes in conditions and performance over time on that same section.

Analytical Issues

Another group of issues concerns the analytical procedures used in investment modeling themselves and the scope of the investments covered in the analysis. These issues include security and emergency preparedness in relation to infrastructure investment analysis, risk and uncertainty in the analyses, lifecycle costs analysis, new technologies and techniques, multimodal analysis, the impacts of infrastructure investment on productivity and economic development, investment on lower functional systems, the scope and scale of the information covered in the report, and other potential applications for the analytical tools.

Security and Emergency Preparedness

The relationship between transportation infrastructure and national security and preparedness is an area of potential improvement in our understanding of investment needs. Transportation obviously plays a critical role in evacuating citizens and providing access for emergency responders in the event of a natural or man-made catastrophe. The effectiveness of such responses depends in large measure on the installed capacity of the transportation system to operate under extreme conditions; thus, some level of transportation investment could conceivably be justified on the basis of improved security. The difficulty, however, is in defining an investment "need" in such circumstances. Is our benefit-cost analysis framework for analyzing potential future investments sufficient when considering investments with such alternative purposes? In particular, how does one define investment needs to handle events with extremely low probability but potentially catastrophic consequences? More generally (and perhaps most importantly), is transportation infrastructure investment modeling the appropriate place to analyze security needs, or should they be derived from an independent review that is more closely tied to Federal, State, and local government policies and priorities?

A related issue is the value of redundancy in the transportation network. By their very nature, key transportation facilities (such as highway bridges or transit tunnels) are vulnerable to becoming disabled during a crisis, or could themselves be targets of an attack. The viability of alternative routes or models of transportation under such circumstances thus becomes critical. A transportation network with many alternate pathways and modes would be advantageous in such circumstances, but providing such alternatives could result in significant redundant, underutilized capacity during the majority (or perhaps entirety) of the time that a crisis does not exist. How should this excess capacity then be valued from a benefit-cost standpoint? Since redundancy is inherently a network phenomenon, modeling its impacts and benefits would require the type of network analysis tools that are discussed below. At the same time, redundancy in the system also plays a role in helping highway authorities deal with major incidents as well as disasters; thus, some of the benefits of redundancy would appear as reductions in incident-related delay.

FTA will be examining the possibility of incorporating increases in security costs external to TERM and incorporating them into its investment analyses.

Risk and Uncertainty

Another feature of an ideal investment analytical process would be a better understanding and exposition of the uncertainty in the estimates of future investment needs, and a system in which such uncertainty is minimized to the extent possible. Improving our understanding of uncertainty in the estimates would require a better understanding of both the impact that key variables have on the estimates and the actual statistical distributions of those variables. The current approach to evaluate such uncertainty used in the report is the sensitivity analysis presented in Chapter 10, but other methods (such as Monte Carlo simulations of confidence intervals) would be possible. However, these methods could involve trade-offs between such capabilities and other refinements in the model inputs and procedures, which would need to be considered before implementation.

Minimizing the uncertainty of the analyses would largely require improvements in the reliability of the data inputs (in addition to model improvements described elsewhere in this chapter). FHWA and FTA have various quality control measures in place in their data collection systems and are continually looking for opportunities for improvement. This is also one of the goals of the current HPMS reassessment described earlier. The Travel Model Improvement Program, sponsored by the two agencies (and described in the 2002 C&P report), is intended to improve the reliability of the future travel forecasts that are key inputs into the highway and transit models. As always, however, the benefits of improved data quality must be balanced against the ongoing or increased costs of collecting that data.

Lifecycle Cost Analysis

In addition to estimating the economically optimal level of future investment, an ideal investment analysis tool should be able to address the optimal timing of that investment by comparing the lifecycle costs of alternative temporal improvement strategies. It should also be able to quantify the trade-offs between early, less aggressive improvements and deferred, more extensive improvements. While the input costs and modeled or assumed improvement lives used in the current investment models are intended to reflect the full lifecycle costs of improvements, this area remains a significant limitation on the methodology in use.

Each of the tools currently used by FHWA and FTA models system investments on a year-by-year (or period-by-period) basis. While the improvements made in one period affect the condition of the system and improvement options available in subsequent periods and benefits are evaluated over multiple periods that an improvement is in use, potential improvements in different time periods are not compared with one another. For example, while a particular improvement on a section may be justified on economic grounds, it could be more advantageous to postpone the improvement to a later time. The models do not currently consider this option, nor do they consider the potential effects of advancing certain actions.

The HERS model is also limited by the way that it evaluates pavement improvements. The decision on whether a resurfacing improvement or full-depth pavement reconstruction is warranted is currently

Q&A

What research projects do FHWA and FTA currently have underway aimed at addressing some of these analytical issues?

FHWA has the following projects in progress in this area:

- **HERS lifecycle cost analysis.** This project will explore different means of bringing more lifecycle cost considerations into the HERS analysis by assessing the timing of investments as part of the benefit-cost analysis procedure.
- **Productivity benefits and economic impacts.** This project is expected to produce two related studies. One will be a white paper exploring the different mechanisms that translate transportation system performance improvements into productivity impacts, and whether any such impacts might warrant inclusion in the benefit-cost analysis procedures. The second will apply HERS analytical results to a regional economic development model to illustrate the true long-term economic impacts of different levels of highway investment.

FHWA and FTA are also jointly undertaking research on multimodal analysis. These exploratory first steps are focused on the existing analytical tools used in the C&P report, examining the benefit-cost analysis procedures and seeking ways that these could be improved and harmonized with each other.

a mechanical one, based solely on whether the pavement condition is above or below a threshold reconstruction level. Ideally, such a decision would be made based on a trade-off analysis between the less aggressive resurfacing option and the more expensive (but longer-lasting) reconstruction.

New Technologies and Techniques

The investment estimates reported in the C&P report are intended to reflect existing technologies and techniques, and FHWA and FTA devote considerable resources to keep the models and methodologies used in the C&P analysis current with transportation industry research and practice. However, it is entirely possible that new technologies and methods might be developed over the course of the 20-year horizon analyzed in the report that could affect the performance of the transportation system and the cost of transportation infrastructure improvements. Such developments might come in several areas, including construction methods and materials, operations strategies and ITS technologies, and transit vehicle technologies.

The FHWA continues to devote significant research resources to improving pavement and bridge technologies, preventive maintenance strategies, and construction methods and management techniques. To the extent that these technologies and techniques extend the useful lives of pavements and bridges, they could reduce the need for future investments in system preservation. Some strategies, however, might also be aimed at reducing the impacts of highway construction on users and adjacent landowners. In many cases, such strategies might involve a trade-off of higher construction costs for lower user impacts during the construction, thus increasing the future costs of capital improvement needs (while still benefiting users of the transportation system).

Highway operations strategies and ITS technology are other obvious candidates for continuing improvement over time. The aggressive deployment and full deployment scenarios analyzed in Chapter 10 assume accelerated adoption rates for operations and ITS, but the investments and strategies themselves are the same as those available at the present time. However, if the effectiveness of such strategies and technologies improves over time or if new technologies were to be developed, then the impact of such investments on highway performance (and thus the investment scenario estimates) would also increase. For transit, new or improved ITS technologies could similarly improve the operation of transit systems, potentially allowing them to provide more service with the same asset base and reducing the need for additional investments.

Highway and transit vehicle technologies are the final area where new development would be expected over time. Future automotive technologies could interact with ITS deployments to further improve operating efficiency and reduce the risk and impacts of crashes and other incidents. Such developments could also apply to transit vehicles. However, some of the new or improved transit vehicle technologies could be aimed at other public policy goals, such as reducing emissions or fuel consumption or improving access for the disabled. New technologies in these areas could have the effect of increasing the future cost of transit vehicles and thus raise the level of investment that would be required to achieve a given level of conditions and performance (though improved accessibility could have some impacts on performance by reducing transit vehicle dwell times).

Multimodal Issues: Benefit-cost Analysis

As described elsewhere in the report, the investment analyses conducted for this report employ three different methodologies, using datasets and models developed specifically for the analysis of highway (HERS/HPMS), bridge (NBIAS/NBI), and transit (TERM/NTD) investment, respectively. This approach offers the advantage of having specialized models that have been designed and adapted to the unique characteristics of each mode and data source. The disadvantage, however, is that the resulting analyses may not be strictly compatible with one another. It also means that the combined total investment scenario estimates for highway, bridges, and transit may not reflect potential trade-offs between alternative investments aimed at addressing the same transportation system-level performance issues. These issues are discussed in more detail below.

Benefit-cost Analysis Procedures

While each of the three investment tools uses benefit-cost analysis (BCA) to some degree in estimating future investment under different scenarios, the models vary widely in how that application is made. The models use different inputs and apply BCA at different points in the improvement selection process, making it difficult to compare the recommended improvement sets on that basis. To a large extent, these differences reflect the distinct data sources and different development histories of each of the tools. The result, however, is that it is difficult to interpret differences in the performance and investment results produced by the models with one another on an economic basis. If the BCA approaches in the models could be harmonized, however, then any cross-modal comparisons would become meaningful, and joint criteria (such as a common benefit-cost ratio threshold) could be applied to each of the separate analytical models, producing some potentially enlightening results about the mix of investments.

Many of the potential methodological improvements described elsewhere in this discussion would ultimately be aimed at improving the quality of the BCA in the models. However, fundamental improvements in the application of BCA also could be made. Investment analysis as practiced for the C&P report involves determining potential condition or performance deficiencies that might warrant correction, and then designing, evaluating, and selecting improvements for implementation that might address these deficiencies. The total level of investment in a given scenario is then determined by imposing some constraint on the final improvement selection process (to tell the models when to stop making additional improvements). Ideally, BCA would be employed at the evaluation and selection stage for particular investments. Among the three investment analytical tools, however, only the HERS model currently operates in this fashion (owing largely to the suitability of its data set and the longer time that the model has been under development). HERS is thus the only one of the three that is able to fully specify an investment scenario solely on the basis of economic efficiency. As a result, much of the discussion within the DOT on improving the comparability of BCA in the models involves modifications to TERM and NBIAS to make them more consistent with HERS, although there are aspects of all three models that warrant consideration for adoption in the others.

TERM currently evaluates the benefits of each transit mode relative to three potential modal alternatives. These are auto (for nondependent riders), a slower transit alternative (e.g., bus instead of rail), and tax (for dependent riders). Provided sufficient information is available, FTA will expand this range of alternatives to include alternatives such as walking, bicycling, sharing the ride, or not making the trip at all.

In TERM, improvements are selected under one of four different modules (see Appendix C). However, only investments selected under the performance enhancement module are directly subjected to a benefit-cost test at the time the improvement is considered. Instead, the benefit-cost test for other improvements is applied at the end of the analysis to the operations of a particular mode and service provider; operator-mode combinations that fail this BCA test then have all their investments removed from the analysis. As a result, decisions on whether to implement particular asset replacements or performance maintenance improvements are strictly an engineering decision, and there are no trade-offs made between alternative investments on a given mode.

Changes made to the NBIAS model prior to the 2004 C&P report have enabled significant upgrades to the benefit-cost component of the analysis, allowing some degree of trade-off analysis between bridge replacement and rehabilitation investment options. However, the BCA conducted in the model remains somewhat fragmented, occurring at separate stages of the analysis and using different procedures that are not closely related to one another.

One of the prime challenges in BCA for bridge rehabilitation and replacement is to adequately capture the impacts of physical conditions on users. Unlike highways, where poor pavement quality can directly affect vehicle wear and tear and operating speeds, poor structural conditions on bridges are largely unseen and do not directly affect the quality of users' experiences as they traverse the facility. Users are thus generally affected only when structural conditions deteriorate to the point where a bridge must be closed or have vehicle weight limitations imposed as a safety precaution. When this occurs, of course, the user impacts can be quite severe, depending on the availability of other nearby options, and are especially significant for the freight trucking sector.

Improving bridge investment BCA will thus require better information on user costs. The key data that would be required for such analytical enhancements include better information on highway use by vehicles of different weight classes and an improved understanding of the relationship between bridge condition ratings and posted weight limitations. Some vehicle weight data may be available from past FHWA studies of highway cost allocation and truck size and weight, but this information would need to be updated more regularly for use in the C&P analyses. Incorporating weight restrictions into the NBIAS analysis will likely require additional, perhaps original, research.

It should be restated that the limitations of the TERM and NBIAS analyses described here are largely due to the nature of the data sources and the types of improvements that they are designed to simulate, rather than to flaws in their design or implementation. The HPMS was originally designed specifically to provide the types of information required for the type of investment/performance analysis reflected in the C&P, whereas the NTD and NBI were developed primarily for other purposes. Increased availability of more specific data would offer significant opportunities for improvement in progressing toward a more complete analysis of transportation investments.

Investment Scenarios

The limitations to the BCA in the different models lead to the disparate scenario definitions employed for highway, bridge, and transit investments in this report (see the Introduction to Part II for more discussion). While baseline "Cost to Maintain" and "Cost to Improve" scenarios are estimated for each of the three modes, the scenarios themselves represent different concepts. For the "Cost to Improve" scenarios, only the HERS scenario is defined on the basis of maximizing net benefits. While TERM and NBIAS use BCA as a screen or filter, improvements are not selected on that basis. Thus, the "Cost to Improve" scenarios for these two models cannot be described in economic terms at the present time; instead, they represent condition and performance benchmarks only, without direct consideration as to the economic desirability of reaching that level of performance (in HERS, the level of condition and performance reached under the "Improve" scenario is a result rather than a specification).

The Cost to Maintain investment concept, on the other hand, inherently involves reaching some future benchmark condition and performance target that corresponds to the current state of the system. Defining this benchmark, however, can be tricky, and various definitions have been used over the life of this report series. For the TERM analysis, the implementation is relatively straightforward, since condition-related and performance-related improvements are estimated independently of one another. In HERS, however, preservation and expansion improvements are modeled simultaneously, and trade-offs are made among improvements with varying impacts on condition and performance. As a result, different levels of investment will correspond to different benchmarks (see Chapter 9). The Maintain User Costs concept represents a reasonable blending of the two, but no comparable measures are available from either NBIAS or TERM in their present form.

The NBIAS "Improve" and "Maintain" scenario definitions are even more limited than those of HERS and TERM. The condition and performance measure used for the analysis is based on the dollar cost of the backlog, rather than an actual system-level physical condition measure. Further work is needed to calibrate the models to allow the calculation and prediction of such condition measures with a sufficient degree of confidence; only then could the NBIAS scenarios to be redefined based on broader performance outcomes.

Finally, it should also be noted that there are important differences between HERS and TERM in their calculations of system condition measures for the "Maintain" scenarios. In HERS, the average IRI measure is calculated for the entire system at any one time. In calculating this measure, no distinction is made between the condition of new lanes and pre-existing lanes. Thus, the average IRI reported at any given investment level will represent the overall state of the system at that time, with the new pavements from newly added lanes fully weighted in. In the TERM analysis, however, the average condition rating measure is applied only to existing and replacement assets when defining the "Maintain Conditions and Performance" scenarios. The impact of new assets intended for system expansion is not included in the calculation of the condition and performance target. As a result, if transit capital funding were to be sustained at the Cost to Maintain Conditions and Performance level, the average asset condition measures representing the state of the entire system would be expected to increase over time, rather than remaining constant.

Network and Multimodal Trade-off Analysis

In addition to analytical comparability, significant multimodal issues exist that concern the independence of the investment results produced by the C&P models. In particular, the models do not take account of the fact that there may be trade-offs between alternative highway and transit investments aimed at addressing the same transportation system-level performance issues. These issues are closely related to the concept of performing analysis at the network level for highways, and both are discussed here.

Network Analysis

One of the key limitations of the highway and bridge investment analyses presented in this report is that the analysis is conducted at the individual segment or bridge level. As a result, investments on any one facility do not have a direct impact on the performance of any other facility in the models. One of the key characteristics of the highway system in the United States, however, is its extraordinary degree of interconnectivity, with numerous intersecting and parallel routes forming a complete network. Changes on one road can affect another; the functional performance of a bridge can significantly impact adjacent roads on either side.

It is clear, then, that a comprehensive highway investment tool would need to be network-based in order to fully capture all of these interrelated effects. However, the challenges involved in constructing such a framework are daunting. First, the highway data used as inputs into HERS are based on a sample of segments on higher-order systems. These sample segment data are sufficient for the national-level analyses performed in HERS. A network analysis, however, would require data on the full universe of highway segments, which would tremendously increase the data collection burden on States. Some representation of rural minor collectors and rural and urban local roads would also need to be made in such a model (though perhaps not each facility individually), further increasing the amount of data needed.

Even if the data needed to feed a national-level network analysis tool were readily available, such a model would be extremely complex and computationally intensive. The network models used by MPOs and State highway agencies are quite costly and complicated, even for analyzing a single region; doing this at the national level could increase this by orders of magnitude. Keeping the scope of the analysis within tractable limits would force simplifications and compromises in other areas of the analysis; there would thus be trade-offs involved in moving to such an approach. The network models currently in use also can be very sensitive to small changes in the network infrastructure. While these reflect the interrelated nature of the network, the magnitude and inconsistency of some of these results far from the location of the improvement may raise questions about how suitable such models are for some policy analysis applications.

While comprehensive network analysis may thus prove to be elusive, it would nevertheless be possible to improve the current models and methodologies that attempt to mimic some of these network effects. While there are no direct linkages among the sample highway segments in HPMS, procedures have been added to HERS to take some network effects into account indirectly. For example, the delay estimation procedures have been calibrated to account for the impact that capacity restrictions on one segment can have on other segments through queuing. The travel demand elasticity procedures used in HERS reflect the fact that traffic may be diverted from or attracted to other highway segments in response to performance changes on the particular segment being analyzed. While this is adequate for purposes of analyzing the benefits and costs of making an investment on an individual section, for purposes of assessing the systemwide impacts of an investment scenario, it would be desirable to track and account for such traffic shifts in a more comprehensive manner.

It might also be possible to make more limited changes to the data collection process that could facilitate some limited network analysis. For example, highway data might be sampled on the basis of corridors rather than segments, with data collected for multiple segments within a corridor. This would allow some intersegment relationships to be captured, while maintaining the advantages of a sample approach.

Another desirable highway network analysis feature would be to link the highway and bridge analyses more directly. In the real world, bridge preservation and other highway improvements in the same corridor are closely related to one another, and significant economies can be achieved if they are scheduled accordingly. This is particularly true for pavement resurfacing/reconstruction and bridge redecking improvements and for bridge capacity expansion and other rehabilitation or replacement improvements; in both cases, these improvements are modeled in HERS and NBIAS, respectively. Linking the two analytical approaches would require linking the HPMS and NBI databases to one another, so that bridges could be properly located on their associated highway segments (a more difficult task than might be intuitively supposed, given the different geocoding approaches used in the two databases). At a minimum, knowing the number and type of bridges on a given highway segment could be used to significantly improve the estimates of highway expansion costs assumed in HERS.

Potential does exist for improving the consideration of network effects in the highway and bridge investment analyses found in this report. At a minimum, future modifications to the model should be structured to make the models more consistent with network principles, rather than less so.

Multimodal Trade-off Analysis

In principle, the network analysis concept could be extended to cover both highway and transit networks. Doing so would allow for an integrated analysis of surface transportation investment, a worthy goal for the C&P reporting process. If such a goal could be accomplished, then the combined total investment scenario estimates for highways, bridges, and transit would reflect the needs of the transportation system generally, rather than simply being a summation of mode-specific improvements.

As with highway network analysis, however, significant and perhaps even larger hurdles would need to be overcome in order to achieve a true multimodal network analysis capability. For highway network analysis, the current data collection process would need to be extended to a much larger portion of the highway system. Multimodal network analysis, however, would require the systematic collection of transit asset and use data on a fundamentally new basis. To link up with highway network data, transit data would be needed on a similarly detailed geographic level. Presently, however, as noted elsewhere in the report, NTD data are collected only at the operator-mode level.

The FHWA Office of Transportation Policy Studies is developing a strategic multimodal framework for studying investments aimed at improving freight flow. While this analysis does not examine highway investment in detail, it is using HERS and other tools to examine investments across different freight modes in key trade corridors.

Since driving cars or riding transit represent alternative choices to users of the transportation system, investments in highway or transit infrastructure are often viewed as substitutes, and a complete analysis would reflect this. The most frequently cited use of multimodal network analysis would be for trade-off analysis between highway capacity expansion and new or upgraded transit investment in a congested corridor. In such cases, a unimodal (or dual-modal) approach might overstate the level of investment required to address the deficiency by recommending that both transit and highway facilities be upgraded to the fullest extent.

Investments for operational performance needs are only one type of capital investment, however. As described in Chapter 7, a significant portion of future investment under the scenarios is for preserving the current asset base. Also, as noted in Chapter 1, there are many complementary aspects to highway and transit investment, such that investments in one can improve the efficiency of the other. Thus, it is not clear that fully considering these cross-modal effects would lead to reduced estimates of highway and transit investment scenarios.

An example of a complementary transportation investment type that is not currently modeled, but that would affect both highways and transit operations, is HOV lanes. Investments in these facilities can both allow for improved transit service in a corridor and affect the demand for highway use by affecting vehicle occupancy rates. Thus, analyzing HOV investments would be an important part of any multimodal investment analysis.

Finally, while multimodal trade-off analysis is often cast in terms of options for intraregional passenger transportation, the concept could conceivably be extended to intercity passenger travel and to freight transportation, and include tradeoff analyses involving air, rail, and water transportation. While such capabilities would be useful for policy analyses of particular issues (such as truck-only lanes), they would also represent an expansion of the current scope of the C&P report, which focuses on highway and transit investment.

Productivity and Economic Development

While the C&P report includes extensive analyses of highway and transit investment, focusing on the system conditions and performance implications of that investment, it does not directly address the impact of transportation infrastructure investment on productivity and economic activity. The 2002 edition of the report included a special topics chapter outlining some of the relationships between infrastructure and the economy. In the context of this view to the future of the C&P report, there are three subjects to be explored: the relationship between productivity impacts and BCA; the economic impacts of transportation system performance improvements; and highway investments specifically targeted to spur economic development.

One of the most prominent effects of transportation infrastructure is the impact that it can have on the location and level of business development. Indeed, this is one of the primary rationales for public involvement in transportation. Such impacts are likely to be most prominent in underdeveloped regions where inadequate infrastructure poses a significant impediment to growth by limiting access to national and regional markets. To a large extent, these impacts simply represent the translation of transportation system performance improvements into economic activity. However, in recent years questions have been raised and theories proposed about whether some of these impacts might represent additional benefits of investment that are not currently captured in BCA. To the extent that such benefits might exist, the current methodology would understate transportation investment benefits by failing to account for this positive externality. At the present time, however, there is significant debate within the transportation research community on this subject, and it remains a controversial topic.

Even if such positive externalities could be identified and isolated, incorporating them into the current methodology could be challenging. Estimating such impacts would require additional information on land use and economic activity in the area surrounding a potential improvement that is not currently collected. Such impacts could well occur in regions not directly adjacent to an improvement, further expanding the scope of the data that would need to be captured.

If it were determined that economic impacts shouldn't be additively considered in the benefit calculations, however, there may still be some merit in measuring such impacts. Since any performance impacts are likely to result in new or relocated economic activity, such measures would represent an alternative illustration of the effects of investment, which could be quite useful to policymakers. This information could also help steer the discussion of the relationship between infrastructure development and the economy away from the transitory, short-term impacts on employment and onto the more permanent impacts that this investment can have on promoting commerce and industry. If such indicators could be reliably and consistently estimated based on the performance results of the investment models, they might make a valuable addition to the traditional analyses presented in the report.

As discussed in Chapter 8, an FHWA study catalogued at least $700 million in highway spending by State governments in 2002 that was specifically targeted at regional economic development. These funds included programs tied to specific economic development outcomes (such as collateral

> The FHWA Office of Freight Management and Operations (HOFM) is conducting research to provide better estimates of the impact of highway improvements on the freight transportation sector. Traditionally, only the benefits to carriers have typically been counted, ignoring the benefits to shippers.
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> The research has documented a range of short-term (first-order) and long-term (second-order) benefits to shippers and carriers from highway improvements. A major first-order benefit is a reduction in transportation costs to individual firms. As the network expands, the number of links increases, making point-to-point trips less circuitous and reducing transport distances. Highway improvements may decrease congestion and travel times. They can also improve reliability, allowing firms to reduce the risk of late deliveries and to reduce inventories and the costs associated with storing goods. Second-order benefits include efficiency improvements and further cost reductions resulting from improvements in logistics and supply chain management and changes in a firm's output or location. As part of this research causal links among highway performance, truck freight rates and shippers' demand for highway freight transportation were estimated.
>
> Additional research is being conducted aimed at the translating the results of the analysis described above into a form suitable for the development of an analytical tool that can be used to allow for a fuller accounting of the positive impacts of proposed freight transportation investments. The tool would differentiate among regions and commodity groups.
>
> More information on this line of research is available at http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods.htm.

private investment) as well as broader economic development programs, some of which may be implemented in conjunction with State economic development agencies.

From the C&P perspective, the key question is the extent to which these types of expenditures are reflected in the investment scenarios. While the investment modeled in this report is aimed at correcting existing condition or performance deficiencies, economic development highway initiatives are intended to meet other goals. In many cases, such initiatives may be targeting existing deficiencies that are seen as a barrier to improved commercial opportunities in a region; this type of investment would likely be included in the C&P estimates as well. In other cases, however, this goal might be met through significant upgrades to the transportation infrastructure that do more than simply address current deficiencies. As discussed in Chapter 7 and the Introduction to Part II, State and local governments may use criteria beyond those employed in the C&P investment analyses, and this portion of economic development highway funding would fall into that category.

The FHWA Office of Interstate and Border Planning is sponsoring research on the economic development impacts of highways. This research looks at the impact of highway investment on economic development from various perspectives. One line of this research has looked at regional development and the types of transportation strategies that can be effective in achieving and sustaining economic growth. Other studies have examined State highway programs targeted at economic development to gauge their extent and impacts. Other research has sought to understand the actual causes and mechanisms through which highways can spur local economic development.

Included in this research effort are a number of before-and-after type case studies of the economic impacts that specific rural freeway and expressway investments have had. This research notes cases where such investment has had success in supporting economic development and cases where it has not, describing some of the broad conclusions about highways and economic development that can be drawn from the studies.

More information on this research is available at http://www.fhwa.dot.gov/planning/econdev/index.html.

Lower Functional Systems

The three investment models used in this report (HERS, NBIAS, and TERM) are all designed to use input data on system characteristics and conditions that are supplied to FHWA and FTA by State and local transportation agencies and operators. The data are assembled into three databases: the HPMS, the NBI, and the NTD (see Appendices A, B, and C for more information). While mandatory reporting requirements are in place for each of these data series, ensuring that the datasets are reasonably rich and complete, the requirements do not cover all roads or transit systems. As a result, the following limitations apply to these data:

- On the FHWA side, only roads in functional classes that are eligible for Federal aid are included in the HPMS sample dataset (though limited data are collected universally), meaning that rural minor collectors and rural and urban local roads are not directly included in the HERS analysis. As a result, potential future investments on these functional classes must be accounted for indirectly, rather than being actually modeled (see Chapter 7).

- Since all bridges on public roads are eligible for Federal aid, the same limitation does not apply to the NBIAS results. However, the bridge-level data items included in the NBI are more aggregate than the element-level inspection data that many States collect, but these more detailed data are not required to be reported to FHWA.

- On the transit side, only transit systems in urbanized areas (over 50,000 in population) that receive Federal funding have been required to report to the NTD. This requirement has excluded transit operators in nonurbanized areas and some providers in urbanized areas (though some nonrecipients do report). SAFETEA-LU has mandated that states report data on rural transit systems to the 2005 NTD. Rural needs are currently estimated outside of the TERM model based on alternative, occasional data surveys and added to TERM's estimates of total investment under the scenarios (see Appendix C).

From a conceptual standpoint, having more complete data from these lower-order systems would obviously improve the precision of the national investment estimates. However, such improvements must be weighed against the reporting burden that would be placed on the providers of the data. Enforcing any mandatory reporting requirements could also be an issue with providers that do not receive Federal funding. As a result, FHWA and FTA are and will be pursuing other projects aimed at improving estimates for these classes of roads and operators.

Scope of the Report

While the Part I chapters of this report include data on both capital and noncapital spending and activities, the investment analyses of Part II focus exclusively on capital improvements. To some degree, this reflects the traditional focus of Federal assistance for surface transportation on infrastructure development, with operating, maintenance, and administrative responsibilities left to State and local governments (see Chapter 1). It also reflects a view that ongoing, noncapital expenditures are simply a cost associated with a given level of infrastructure provision, rather than representing long-term investment needs.

There are two issues that have been raised concerning the capital focus of the report. First, as noted above, operations strategies and preventive maintenance are increasingly being seen as a partial alternative to infrastructure investment in today's world, as part of an asset management strategy, rather than simply as a cost of doing business. How should this best be reflected in the investment analyses presented in this report? The discussion of highway operations strategies in Part II reflects our initial effort along these lines, but this presentation is likely to change over time as our thinking on this subject evolves.

Another issue regarding the focus on capital outlay is that it does not fully inform policymakers about the true cost of program delivery. While agencies strive to streamline their programs and systems to the extent possible in order to stretch limited funds as far as possible, new mandates and legislative requirements may make this more difficult. If such trends are present and growing into the future, then more overall resources would be required to sustain a given level of capital investment. Should the investment scenario estimates reflect such possibilities?

A final scope issue concerns the particular modes that are included in the report analyses. The highway and transit conditions and performance reports series were originally prepared separately, reflecting the fact that the legislative requirements for the reports were found in separate parts of the *United States Code*. Since 1993, these analyses have been combined into a single report; SAFETEA-LU altered the legislative mandate by including transit in the scope of the report defined in Section 502(h) of Title 23. However, while these two modes are both economically significant and closely related, they do not represent the entirety of the Nation's surface transportation system. In particular, conditions, performance, and investment analyses for intercity rail and bus, maritime transportation, inland waterways, railroads, and port and international gateway facilities are not included in the report. While some of these modes are typically characterized by private sector control over management, finance, and investment, others do have substantial public involvement in their infrastructure financing. Past analyses (such as the 1995 report) have included discussions of some of these modes, and recent reports have included additional analyses of specific components of the system (such as transit on federal lands, highway-rail grade crossings, and intermodal connectors).

Changing the scope of the C&P report on any of these accounts would represent a significant change in the character of the report. They would thus require extensive consultation with policymakers and stakeholders before implementation. More generally, the issues listed above, and many of the topics discussed elsewhere in this Afterword section, ultimately relate to the basic purposes of the C&P report. Should it become a comprehensive source for a variety of transportation policy analyses; or should it retain its focus on national-level conditions, performance, and investment scenario reporting? Do the special topics and analyses that have been included in the report in recent years add useful breadth to the report, or do they ultimately distract from its central purpose? If these other analyses and information would truly be useful to Congress and other policymakers, one option would be to provide them in separate reports, allowing the C&P to retain its basic character and function. Separate reports could also be more focused on key policy issues than would be possible in a more inclusive document.

Extensions of the Analysis

A final topic concerning the future of the C&P report relates to extensions of the analysis to other purposes. The DOT and its agencies have devoted considerable research and staff resources over many years to the analytical tools developed for this report series. Are there ways that this investment could be leveraged beyond the C&P report itself? Two potential areas come to mind: using the tools in other contexts and bringing the tools to other agencies.

The C&P analytical tools represent a blend of analytical sophistication and limitation commensurate with the purposes that they serve. Are they appropriate for use in other policy analyses as well? If the models are to be used in other contexts, they may require some customization and fine-tuning for those purposes. Such efforts could require diverting resources from other model development work, and care would need to be taken to ensure that any resulting changes would not interfere with the operation of the models for C&P purposes. More importantly, could the models produce misleading results if used out-of-context? The FHWA is currently exploring such extensions of the HERS analysis for studying freight bottlenecks. The longer-term pavement modeling research described above is also being conducted to ensure that the basic pavement deterioration modeling approach is consistent in both HERS and in tools used for highway cost allocation studies.

The legislative language authorizing the National Surface Revenue and Policy Study Commission authorized in Section 1909 of SAFETEA-LU directs that study to include analyses of future investment needs. The final report of the commission is due to Congress in September 2007. While the results from this edition of the report are expected to inform the commission's findings, the analytical tools themselves may also be employed in the course of the commission's work to develop scenarios specifically tailored to its mandate.

Another extension of C&P research is to offer the use of the analytical tools to other stakeholders outside of the DOT. The FHWA has developed a version of HERS for use by State highway agencies, known as HERS-ST. The agency has actively promoted HERS-ST as an asset management tool since its initial release in 2002 and has provided training and support for the software to a number of different states. Local transportation agencies and regional planning organizations have also expressed interest in the tool. These efforts allow others to benefit from the research and development that FHWA has conducted. By helping to improve decision-making about capital investments at the State and local level, they also make it more likely that the estimated performance level associated with a given level of investment can be achieved. Finally, by extending the use of the HERS model, FHWA is receiving valuable insights into the operation of the model and suggestions for future enhancements. The FHWA and FTA are considering whether similar outreach efforts might be warranted for the other analytical tools.