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Valuing a Mature Highway System

In Search of the Holy Grail

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For years, researchers have sought the one true estimate of the value of highway infrastructure—the single number that policy makers can use to ensure the country is equipped with an optimal network of highways. Despite the efforts of hundreds of studies, the search for the Holy Grail of highway valuation has proved quixotic.

In theory, no single estimate can express the value of transportation infrastructure. Because highway infrastructure has network characteristics

From congested urban areas (*above*) to rural roads (*below*), the many components of the Interstate Highway System create a challenge for estimating the value of transportation infrastructure.

Photo: Nicholas A. Tonelli

Photo: Erika Celeste/Michigan Radio

A strip mall on a reclaimed mine site in Logan County, West Virginia. As the economic drivers of an area change, so do the uses of its roads.

and serves the public good, the returns vary from one part of the highway system to another (*1*). For example, adding miles to a congested segment of an Interstate can improve traffic flow and safety. Consequently, measuring the value of highway infrastructure for a congested section of the Interstate system in a crowded metropolitan area would yield a higher return than for a deserted stretch of Interstate in the Great Plains, although both segments are part of the same network.

In addition, changing economic conditions may alter the value of highways over time, particularly at the subnational level. An example is access to the coalfields of West Virginia—as coal deposits are depleted, and as lower carbon-emitting fuels replace coal, the economic value of the roads supporting the coal industry decreases.

These theoretical and practical reasons impede the ability to estimate one ideal value for the effects of transportation infrastructure. Nevertheless, with the maturing of the highway system and the consequent need to understand and account for the transportation services that flow through the system, policy makers and practitioners today need a reliable estimate even more than in the past.

Supply and Demand

The highway system is at a mature stage of development. President Eisenhower's signing of the Federal-Aid Highway Act of 1956 led to the creation of the Interstate Highway System. Today, more than 220,000 miles of Interstate highways are in place, compared with only a smattering of four-lane, limited-access highways in a few states 60 years ago.

The period of great expansion of the Interstate system prompted an even greater increase in highway usage. Between 1980 and 2004, for example, vehicle miles traveled (VMT) on Interstate highways increased by 143 percent, while Interstate lane miles expanded by only 17 percent. Similarly, VMT on all other roads increased by 82 percent, but lane miles on those roads increased by only 5 percent.

Nevertheless, in the past 10 years, the relationship between increases in VMT and in lane miles has stabilized, suggesting a more mature system. Between 2004 and 2014, both VMT and lane miles for the Interstate Highway System increased at approximately the same rate—around 4 percent.

Furthermore, the number of ton-miles shipped by trucks decreased slightly between 2002 and 2012, although trucks claimed a higher percentage of total ton-miles shipped, and the value of truck shipments per ton increased by nearly 30 percent, after a decline in value between 1993 and 2002. Although the Great Recession undoubtedly has affected trends during the past 10 years, the highway system clearly is maturing.

This is consistent with the decline in the net rate

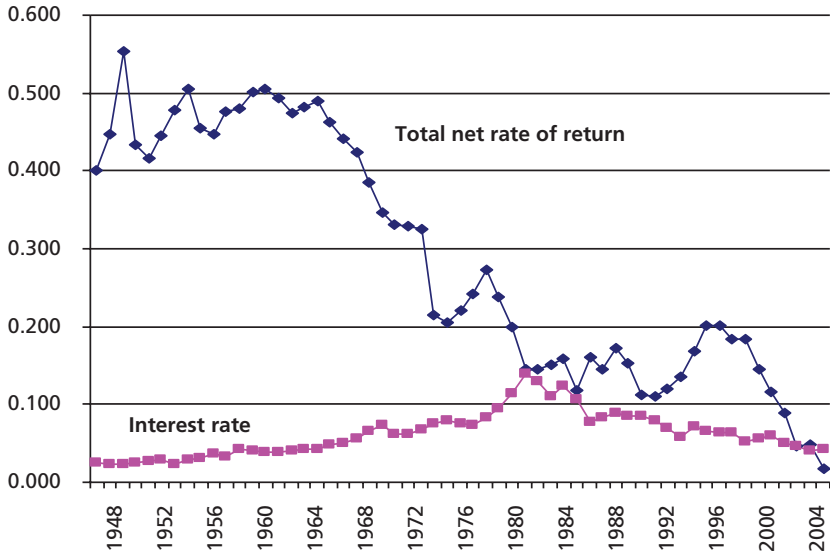

FIGURE 1 Net rate of return of highways and interest rates. [Source: Author's analysis of estimates by Mamuneas (*2*).]

of return from highways during this time. As shown in Figure 1 (above), Mamuneas finds that before 2004, the net rate of return was greater than the marginal cost of highway investment; this is consistent with VMT and ton-miles growing faster than the expansion of the highway system's lane miles (*2*). Starting around 2004, however, the marginal benefits and marginal costs converged; the convergence of highway usage and the expansion of lane miles is consistent with a mature highway system.

Although VMT per lane mile has leveled off in recent years, traffic on many portions of the U.S. highway system remains heavy. Nevertheless, building new highways appears less attractive, perhaps because the marginal benefit of an added mile of highway barely covers the marginal cost, as the estimates by Mamuneas suggest. If building new highways is less likely, then using the current roads with increased efficiency is imperative, to avoid an increase in travel time and a reduction in reliability and safety.

System Transformation

New Technologies

Instead of focusing on laying down asphalt and concrete, investment decisions will need to coordinate the public and private sectors to work together in transforming the highway system into much more than ribbons of pavement. The system instead will be a well-integrated network of pavements, embedded electronics, surveillance cameras, satellite images, and signals—an intricate maze on which intelligent vehicles will navigate.

For the public and private sectors to make the appropriate investment decisions to bring these technologies together, accurate pricing for the components and accurate estimates of the returns, individually and together, are a necessity. Private-sector businesses are likely to be reluctant to invest in the development of new technologies for highway transport without knowing with reasonable certainty the expected returns on the investments.

These estimates require an understanding of

Photo: C. Hanchey/Flickr

The parallel I-25 bridges over Nogal Canyon in New Mexico were completed in 1968; they are on the Federal Highway Administration's list of Nationally and Exceptionally Significant Features of the Federal Interstate Highway System.

PHOTO: JAAN/FLICKR

Before 2004, vehicle miles traveled (VMT) grew faster than the expansion of Interstate lane miles; VMT per lane mile since has leveled off.

highway system characteristics and of the technologies in development to enhance highway safety and reliability. Some technical advances, such as the navigational systems on cars and trucks, require little interaction with the physical characteristics of the roadways, except for warning drivers about construction sites and accidents.

Other technological features on vehicles depend more on the physical condition of the highway infrastructure. For example, features installed on vehicles can warn the driver about inadvertent lane changes. These kinds of devices depend on well-defined lane markings. If the lane markings are nonexistent or have faded because of wear and neglect of the highway surface, the systems will fail, and the drivers who depend on the warnings will be placed in jeopardy.

Driverless cars—likely to be on the roads within the next decade—rely on a complex combination of sensors and computers to pilot through the confusing obstacles drivers confront every day. With the advent of these vehicles, state departments of transportation may have to change priorities from straightening curves to focusing on painted lane dividers to achieve safer roads.

New Priorities for Maintenance

Because many technologies rely on well-maintained highways, proper highway maintenance is paramount. According to a recent report from the International Transport Forum (ITF), "deferring maintenance can make roadway costs much greater than indicated by current expenditures" (*3*). The authors emphasize the long-term problems caused by deferring maintenance, such as the increased cost of restoring a road surface to acceptable conditions after long neglect.

The immediate problem is that many of the new and forthcoming technologies cannot operate optimally without proper maintenance. The authors of the ITF report conclude that proper attention to maintenance requires more detailed metrics for pavement conditions and for other physical conditions of highways.

Expanding the Scope of Benefits

In addition to collecting metrics that capture the physical characteristics of highways more accurately, an expanded understanding of the benefits generated by highways is necessary. Benefit–cost analyses typically focus on travel time, safety, and reliability. Recent research has expanded the scope of benefits to include several types of externalities, which are important in reflecting the full benefits of highway investment.

UK Framework

According to a report from Cambridge Systematics, the United Kingdom may be the furthest along in formulating a framework and in filling in the details of procedures and methods to make economic evaluation "a driving factor in transportation investment decisions" (*4*, p. 1).

The UK approach, developed by Sir Rod Eddington and known as the Eddington Report, attempts

Embedded data loggers are installed to assess concrete strength. The future highway will be a maze of technologies and signals on which intelligent vehicles will operate—investment decisions require accurate pricing and estimates on the returns.

Photo: Utah DOT

to identify and quantify wider benefits of transport investment than are captured in traditional benefit–cost analyses. The Eddington Report identifies seven microeconomic mechanisms that transport investments can influence, including externalities such as increased business efficiency through time savings and improved reliability for business travelers, freight, and logistic operations and the attraction of globally mobile activity through a thriving business environment and a good quality of life.

SHRP 2 Guidance

A report from the second Strategic Highway Research Program (SHRP 2) follows an approach similar to Eddington's by prescribing ways to include the wider benefits of externalities, environmental impacts, labor market efficiencies, and business efficiencies into standard benefit–cost analyses (5).

The SHRP 2 guide targets three classes of wider effects: reliability, intermodal connectivity, and market access. These benefits go beyond the traditional measures of traveler impact, which are based on average travel time and travel cost, and include factors that enable businesses to gain efficiency by reorganizing their operations, by opening access to a pool of talented workers, or by changing the mix of inputs to generate products or services.

The tools to incorporate these benefits within benefit–cost analyses draw on a searchable database of ex post evaluations of 100 projects across the country. Also included is an expert system that draws from the database to estimate the range of the likely economic impacts of any kind of project in any defined setting (5, p. 3).

Although an advance from the traditional benefit–cost approach, the SHRP 2 technique still falls short of the broader issues facing highway investment—namely, the interface with technology primarily emanating from the private sector.

Quantifying Benefits

How important are these wider benefits within a mature highway system? The system is so large that any investment—even a major investment—may not be large enough to make a difference in total travel time.

An example of lane-detection algorithm outputs; like many new technologies, lane detection requires proper road maintenance to work.

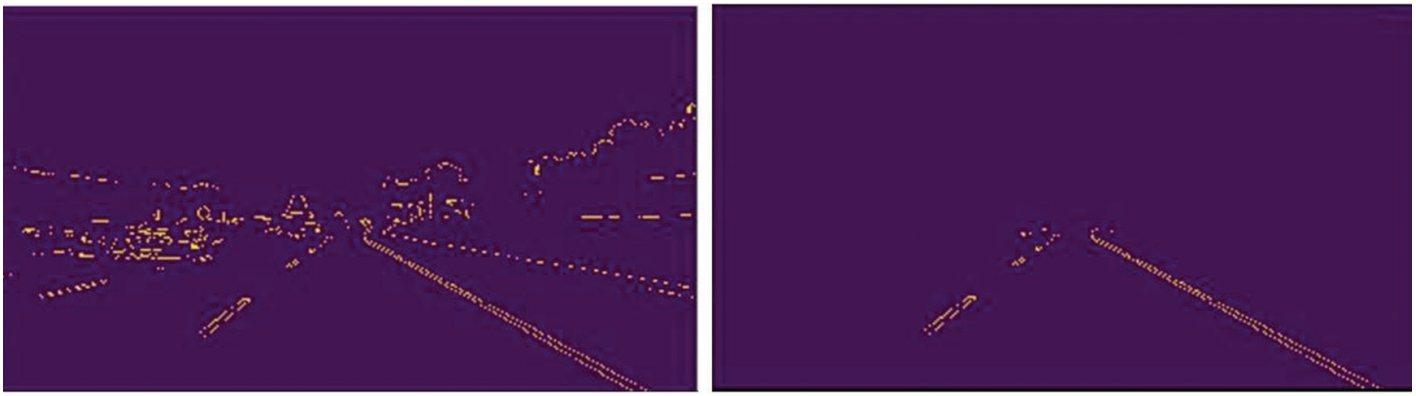

Image: Vidyak/Wikimedia Commons

Some markets with positive externalities, however, may be amenable to greater accessibility through transportation improvements. For those markets, transportation investment can reduce production costs, improve productivity, enable more efficient use of resources, and expand output. Many of these externalities depend on geography; this indicates the need to emphasize the broader benefits in state and local analyses of the value of highway infrastructure.

The benefits of a mature transportation system may be more difficult to quantify than those of a less developed system. In 2012, the panel for a National Cooperative Highway Research Program (NCHRP) project concluded that a mature highway system makes understanding the link between transportation services and economic outcomes much more difficult (*4*).

One reason is that transportation services, particularly within a mature system, are woven into the economic fabric of the nation, so that studying the effects of the services is difficult—and isolating the services from others that are closely interconnected is even more difficult. The NCHRP report raised the conceptual issue that limitations on available data hamper analyses of the causes and effects for actions that optimize service within a mature system—in contrast with a system that is expanding with completely new facilities (*4*, pp. 1–2).

Framework for the Next Stage

Nonetheless, the modular approach of SHRP 2 and the Eddington Report provides a framework for the next stage in estimating the value of highway infrastructure, by integrating new technologies into the traditional highway infrastructure and incorporating the wider benefits of highways into benefit–cost analyses. Many of these advanced technologies—such as collision aversion, navigational advances, and others in the driverless cars undergoing trials—are already in use, and researchers have identified and estimated the wider benefits.

Theory and changing economic conditions make clear that researchers will never find the one true estimate or Holy Grail of the value of highway investments. Instead, the search for methods to value the highway system with accuracy must start by developing appropriate evaluation methodologies for the realities of the present system.

All indicators confirm that the highway system is maturing. Investment decisions therefore require a keen understanding and monitoring of the physical characteristics of the system and of the broader perspective of the economic and societal benefits of highways.

PHOTO: STELLA PICTURES/FAIRWAY FLYOVERS FOR HIGHWAYS ENGLAND

Catthorpe junction on the M1 near Leicestershire, England. In the United Kingdom, the evaluation of transportation assets identifies the microeconomic mechanisms that transportation investments can influence.

More advanced methodologies, such as that developed through SHRP 2, can help decision makers estimate the value of highway infrastructure within this new context. Nevertheless, these more advanced methodologies are only in their infancies, and more work is needed so that benefit–cost analyses take into account the increasing use of private-sector technology to enhance the safety and reliability of highways.

Highways are an integral part of the U.S. economy and of the nation's ability to compete globally—this role will only intensify. Appropriate and accurate evaluation tools must be available to public decision makers and to private businesses to ensure that the required investments are made to keep the nation's highway system viable today and into the future.

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SHRP 2 Project Brief

CAPACITY PROJECT C11

Tools for Assessing Wider Economic Benefits of Transportation

JUNE 2014

Three Classes of Transportation System Impacts

SHRP 2

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For more information on SHRP 2 Capacity Project C11: Development of Tools for Assessing Wider Economic Benefits of Transportation, see the project brief at www.trb.org/Main/Blurbs/170902.aspx.