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Implementing technology to improve public highway performance: A leapfrog technology from the private sector is going to be necessary

Clifford Winston [a,*], Fred Mannering [b]

[a] Brookings Institution, USA
[b] Purdue University, USA

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ABSTRACT

Policymakers could implement available, well-tested technologies to improve the efficiency of highway pricing, investment, and operations, which would improve travel speeds, reliability, and safety and reduce highway expenditures. Unfortunately, political and bureaucratic impediments to implement such technology exist and are unlikely to be overcome in the near future. However, technological innovations underway in the private sector, especially the driverless car, are likely to eventually leapfrog the technology that the public highway authorities could and should implement and will enable road users to obtain most of the potential benefits from technological advances in highway travel.

1. Introduction

The nation′s road system is vital to the U.S. economy. Valued at close to $3 trillion, according to the Bureau of Economic Analysis of the U.S. Department of Commerce, 75 percent of goods, based on value, are transported on roads by truck, 93 percent of workers′ commutes are on roads by private automobiles and public buses, and by far the largest share of non-work and pleasure trips are taken by road (Winston, 2013). Indeed, roads can be accurately characterized as the arterial network of the United States.

Unfortunately, the arteries are clogged: the benefits that commuters, families, truckers, and shippers receive from the nation′s road system have been increasingly compromised by growing congestion, vehicle damage, and accident costs. The Texas Transportation Institute′s latest *Urban Mobility Report* puts the annual cost of congestion to the nation, including both travel delays and expenditures on fuel, at more than $100 billion. Despite frustratingly frequent lane closures for road repairs, federal and state highway agencies′ expenditures cannot seem to outpace the rate of road-infrastructure deterioration. Data from the Federal Highway Administration′s annual publication *Highway Statistics* indicate that although the condition of the nation′s highways and bridges varies with general economic conditions, as much as one-third of the nation′s highways may be in poor or mediocre condition, and one-quarter of the nation′s bridges may be functionally obsolete or structurally deficient. Driving on damaged roads is estimated to cost U.S. motorists $80 billion in additional annual operating costs and vehicle repairs (The Road Information Program, 2013) and has also been shown to damage trucks and increase their operating costs. Finally, although highway safety has improved during the past few decades, because of greater enforcement of drunken driving laws, improvements in vehicle safety, and other factors, traffic fatalities are still one of the leading causes of non-disease deaths in the United States, exceeding more than 30,000 lives annually.

Economists have repeatedly pointed out that policymakers have failed to address highway inefficiencies by implementing efficient road pricing for cars and trucks and by making efficient investments based on cost-benefit analyses.[1] And they have tried to understand the political and institutional impediments to implementing efficient highway policies, and have suggested ways to overcome them, but inefficient policies persist (Winston, 2013).

In this paper, we take a different perspective and argue that policymakers could implement available, well-tested technologies to make highway pricing, investment, and operations more efficient, which would improve travel speeds, travel-time reliability, and safety and reduce highway expenditures. Indeed, in contrast to the technological advance in the comfort, performance, and safety of the vehicles that use the roads, which may reach new heights with the development of the driverless car, technological improvements in the way roads are priced, designed, constructed, and operated have been relatively modest. A technology-based approach to improving highway performance would be particularly attractive because innovations

[1] Mohring and Harwitz (1962) developed a model of efficient long-run pricing and investment rules for highways that provided the foundation for research in this area. Recent models of highway pricing and investment have accounted for demand uncertainty, lumpy investment, heterogeneous users, and so on (Lindsey, 2012).

* Corresponding author. Tel.: +1 202 797 6173.
E-mail address: CWinston@brookings.edu (C. Winston).

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that increase efficiency have taken on renewed importance in today's slow-growth economy.

Unfortunately, the aforementioned political and institutional impediments also apply to implementing new technology on public highways and they are unlikely to be overcome in the near future. However, the private sector is developing new technological innovations, especially the driverless car, which will eventually leapfrog the technology that the public highway authorities could and should implement today, thus providing road users with most of the potential benefits from technological advances in highway travel.

2. Highway characteristics and technologies that could improve performance

Highways provide capacity to allow a flow of different types of vehicles, including passenger cars, buses, and heavy trucks, to travel simultaneously and they are designed to provide a specified level of durability to bear the weight of different vehicles, particularly heavy trucks, and to resist surface wear and structural damage to pavements and bridges. Technologies that help expand capacity and increase durability can increase the flow of traffic and the effective lifetime of a highway (before resurfacing or reconstruction is needed).

Capacity is a function of speed limits, the number and width of lanes and shoulders, and other factors; it is reached well after the road has become congested. Economists characterize congestion as occurring when vehicle speeds decline from free-flow speed, which is the observed speed when traffic-flow is light. The Transportation Research Board (2010) has determined that freeways have a capacity of 2400 passenger-cars/hr/lane with a free-flow speed of 70 mi/hr while freeways have a capacity of 2250 passenger-cars/hr/lane with a lower free-flow speed of 55 mi/hr. As greater traffic volume causes the road's capacity to eventually be reached, speeds on those freeways fall to 53.3 miles/hr and 50 miles/hr, respectively.[2] Additional traffic then causes the density of vehicles to exceed freeway capacity creating an unstable traffic flow, which is characterized by stop and go traffic. Traffic engineers define this outcome as "hyper-congested conditions," in which travel speeds can decline rapidly.

For freeways, the preceding travel conditions are summarized in Fig. 1 in terms of the relationship between speed and traffic flow (in passenger-cars/hr/lane). The speed-flow relationship has been shown empirically to be parabolic; thus, two speeds are generally possible for every given flow: one in uncongested or congested conditions (traffic densities less than or equal to 45 passenger-cars/mile/lane); the other in hyper-congested conditions (traffic densities greater than 45 passenger-cars/mile/lane). For the same level of traffic flow, the portion of the curve in hyper-congested conditions results in a much slower traffic speed than does the portion of the speed-flow curve in uncongested or congested conditions. Transportation officials in many metropolitan areas attempt to prevent motorists from experiencing hyper-congested conditions on freeways by, for example, putting stop and go signals on on-ramps to slow the flow of additional traffic.

Durability depends on pavement thickness, material composition, and other factors such as drainage and climate, as well as on the bridge design. Pavements become worn as the cumulative number of vehicles passing over them rises, and they eventually require resurfacing or reconstruction. Damage caused by a vehicle to the pavement depends on its weight per axle, rather than on its total vehicle weight. The damage caused by an axle is defined in

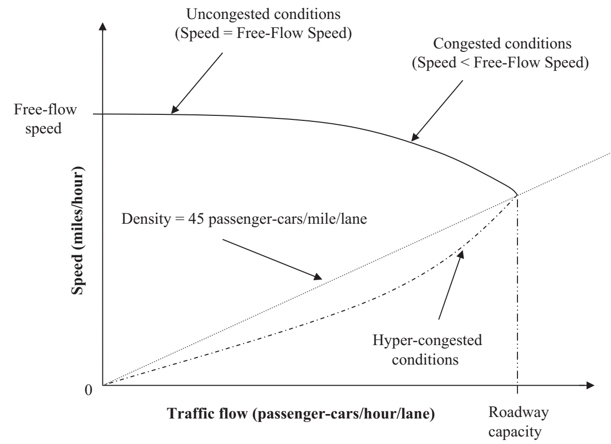

Fig. 1. Illustration of the parabolic speed-flow relationship for freeways.

terms of the number of "equivalent single-axle loads" (ESALs) causing the same damage; the standard is a single axle of 18,000 pounds. Small and Winston (1988) found that the damage caused by a heavily-loaded vehicle rises with the third power with its load. Almost all pavement damage tends to be caused by trucks and buses because, for example, the rear axle of a typical 13-ton trailer causes over 1000 times as much pavement damage as that of a car.

Bridges become stressed as the cumulative number of heavy vehicles passing over them increases and they need to be rehabilitated before they experience catastrophic failure, as in the Minneapolis incident in 2007 that resulted from additional vehicle weight on a bridge that exacerbated a design flaw. The bridge wear that is caused by a truck depends on its total vehicle weight, roughly in proportion to its third power (Moses et al., 1987).

Private and public enterprises enhance their efficiency by implementing technologies that are the products of their research and that have been developed by other entities. The Federal Highway Administration (FHWA) appears to have foreclosed the first option because its budget devotes only a small amount of funds for research and development. Specifically, $400 million of its roughly $40 billion fiscal year 2013 budget is allocated under research programs, but only half of that amount actually funds promising research and development. In contrast, FHWA's administrative expenses exceed $450 million.[3]

New general purpose communication technologies (Bresnahan and Trajtenberg, 1995) as well as specific highway and vehicle technologies give highway authorities the opportunity to make more efficient use of the current vehicle-carrying capacity and durability of public highways by setting accurate marginal cost prices for road users and by adjusting investments and operations to respond to real-time variations in highway travel demand. General purpose technologies include global positioning system (GPS) satellite navigation services that, among other things, collect information about motorists, such as their location and speed, and that can suggest alternative routings for their journeys; Bluetooth signals that can be detected to monitor the speed of cars and trucks throughout the road system in real time in order to assist drivers' route choice decisions and to adjust traffic signal timing; and mobile software applications (apps) and websites that provide motorists with real-time information about driving conditions throughout a highway network and about available parking spaces. Motorists are becoming increasingly aware of the benefits of GPS systems that provide real-time traffic information; accordingly, the share of cars on the road that are equipped with those

[2] At capacity, density for freeways is 45 passenger-cars/mile/lane regardless of free-flow speed (Mannering and Washburn, 2013; Transportation Research Board, 2010).

[3] Those figures are from http://www.fhwa.dot.gov/map21/ha.cfm.