Impact of Fuels and Technology on Transportation Revenue and Finance

Gerry Bemis, *California Energy Commission*
Marianne Mintz, *Argonne National Laboratory*
Lowell Clary, *Florida Department of Transportation*
David Forkenbrock, *University of Iowa*

Forecast Availability and Cost of Petroleum-Based Fuels

Gerry Bemis

Today I would like to discuss some basic findings concerning forecast trends in gasoline and diesel demand (which will continue to grow), gasoline and diesel prices (which will remain below historic levels until at least 2020), and the effects of changes in fuel choices on revenue generated from federal excise taxes.

To lead off, let's look at crude oil supplies. California refineries processed about 1.8 billion barrels of crude oil in 1999, and the demand continues to grow. Foreign supplies constitute an increasing fraction of our crude oil and will make up more than 50 percent of our oil by 2012. Some worry about that, but crude oil is a global commodity and is priced accordingly, and a shortage anywhere is a shortage everywhere.

Now, some believe that the end of cheap oil is near. But others look at reserve appreciation increases, knowing that the new supplies added to the reserves have kept pace with our incremental consumption and continue to extend the life of the reservoir. Basically, geologists tend to be in the first camp and economists in the second camp. The California Energy Commission believes that the transition from crude oil is, in fact, inevitable, but not in the near term.

What is happening with crude oil prices? Real—that is, inflation-adjusted—prices ranged from $10 to $25 per barrel from 1880 to 1980. From 1980 to 1986 the Organization of Petroleum Exporting Countries controlled prices, which resulted in much higher prices. But since 1986, prices have again ranged from about $10 to $25 per barrel. We forecast the prices for 2000 to 2020 to range from $13 to $29 per barrel or so.

Let's focus for a moment on California's gasoline demand. We saw steady growth from 1965 to 1990, followed by fairly flat growth from 1990 to 1998, reflecting some economic doldrums. Recently things have picked up again, and we forecast robust growth in gasoline demand for the 1990 to 2020 time frame. Incidentally, California's consumption of gasoline accounts for a little more than 10 percent of the country's consumption and probably about 3 percent of the world's consumption.

Now let's look at trends in California fuel excise tax revenues, which showed steady growth from 1965 to 1990 in nominal dollars, highlighted by some step increases in the early 1990s because of per-gallon tax rate increases. We forecast continued steady growth through 2020, assuming existing tax rates. But before we get too heavily into the gasoline price forecast, I need to say that long-term gasoline prices tend to correlate well with crude oil prices. We use smooth data with a correlation coefficient of 0.74, which means that 74 percent of the variation in gasoline prices can be explained by the crude oil prices. Short-term gasoline prices tend to show more variation in price components.

When you look at historical and projected gasoline prices in real terms, you can see that our prices today, which seem high because they are close to $0.53/L ($2.00/gal), are really not that high compared with the historical trends. People tend to forget that we have had the benefit of quite low prices for the last several years.

California prices tend to be a little bit higher than the national average—typically in the range of $0.04/L ($0.15/gal) higher. There are several reasons for this difference, including the fact that California's gasoline must be reformulated to California's unique specifications. It is a very clean fuel and costs more to produce. As a result, when California has a supply shortage, it is hard to bring in replacement supplies, and that does not happen unless prices are high enough for long enough to motivate somebody to bring in those supplies.

California is using about 95 percent of its current refining capacity, yielding a very delicate balance between supply and demand. There is not much reserve capacity. When a refinery has a problem, we have a shortage, and in turn we have some real price bites.

We started using methyl tertiary butyl ether (MTBE) in our reformulated gasoline in 1996, but we are now finding MTBE in our groundwater and some drinking water supply wells, which had to be shut down because the MTBE makes the water taste like turpentine and nobody wants to drink it. California's Governor Davis ordered a ban on MTBE on March 25, 1999, and directed development of new forms of reformulated gasoline to be implemented by December 31, 2002. This will allow us to comply with the federal Clean Air Act requirements, though we are currently seeking a waiver from the oxygenate provision because we have demonstrated that refiners can make a cleaner gasoline without using any oxygenate.

We expect an increase in our use of ethanol by 2003. If California gets a Clean Air Act waiver, California reformulated gasoline will need 54,000 barrels of ethanol per day. Without the waiver, the need will rise to about 85,000 barrels per day, accounting for at least a 50 percent increase in the nationwide demand for fuel-grade ethanol.

Oftentimes California is a bit ahead of the rest of the country, and indeed about a year after our ban on MTBE, the Clinton administration announced its intent to ban the use of MTBE in reformulated gasoline, for the same reasons. Assuming a nationwide MTBE ban, we expect a demand of about 10 billion L (2.7 billion gal) by 2003. That is equivalent to 176,000 barrels per day, including California's consumption.

This is significant given the federal ethanol tax subsidy. The subsidy supports renewable feedstocks used to make ethanol, used in transportation fuel. The subsidy is currently at $0.14/L ($0.54/gal) and will gradually decline to $0.135/L ($0.51/gal) by 2005. The subsidy is up for reconsideration in 2007.

The ethanol subsidy reduces funds flowing into the Highway Trust Fund. The most recent highway and transit reauthorization, TEA-21, links highway budget levels to revenue levels under a feature called revenue-aligned budget authority, so the effect of this reduction would be absorbed by all states through the apportionment process. As conditions currently stand, we can expect what I would consider a significant reduction in excise tax revenue.

The other trend affecting tax revenues is corporate average fuel economy (CAFE) requirements. These represent standards imposed on vehicle manufacturers. Currently the standard is 11.7 km/L (27.5 mi/gal) for automobiles and 8.6 km/L (20.2 mi/gal) for light trucks. Sport utility vehicles qualify as "light trucks," and for the first time in many years, average on-road fuel economy is declining because of the penetration of those vehicles into the fleet.

We have prepared some forecasts that project California's Highway Trust Fund revenue from state and federal tax through 2020. The forecasts assume an array of scenarios including the effect of increased market penetration of alternative-fuel vehicles, higher fuel prices, increased use of ethanol in reformulated gasoline, and higher vehicular fuel economy. In short, here are the findings.

With regard to alternative-fuel vehicles, we do not anticipate a big dent in fuel tax revenues by 2020 because of a higher number of these vehicles. With respect to fuel prices, if gasoline prices rise to $0.53/L ($2.00/gal) nationwide, we may see a bit more of a reduction in revenues because of reduced demand for travel, but not that much of a reduction from the base case. And how about ethanol? Ethanol use in reformulated gasoline, assessed both with and without the federal Clean Air Act waiver, causes only a slight decline in the rate of revenue growth, but it causes a wholesale reduction in revenues, akin to a downward shift in the revenue curve. I should note that this shift does not appear in the paper I prepared for this conference because I neglected to deduct a 0.7-cent/L (2.5-cent/gal) component of the overall tax rate that is redirected from the Highway Trust Fund to the general fund for so-called gasohol.

The other action that produces a really significant negative effect on revenues is an increase in corporate average fuel economy. If CAFE increases to 13 km/L (30 mi/gal) for light trucks and to 17 km/L (40 mi/gal) for automobiles, there is not much of an impact until 2007 or so, and then suddenly we see a downturn in revenues. By 2020 we are looking at revenues of about $5.5 billion per year in California under this scenario, versus about $7.1 billion under the base case. To summarize, alternative-fuel vehicles in themselves are not expected to significantly affect Highway Trust Fund revenue. The ethanol subsidy does, in fact, affect revenues, both in the near term and in the longer run. CAFE trends will also become increasingly important in the longer term.

My recommendations stem from a recognition that crude oil prices are, in fact, uncertain. I believe that excise taxes should be indifferent to fuel choice. In this way, if there are a lot more alternative-fuel vehicles entering the market than we forecast, then road excise tax revenues will likely not suffer. For this reason I recommend evolving taxes so that they are levied on a Btu (or energy-content) basis rather than on a volumetric basis. I will leave it up to those of you in the finance profession to figure out how to do that.

Alternative-Fuel and Hybrid Vehicles: Timing and Market Share

Marianne Mintz

This afternoon I will be talking about three aspects of alternative-fuel and hybrid vehicles that could affect motor-fuel tax revenues. First I will discuss tax rates on alternative fuels vis-à-vis those on gasoline and diesel oil. Then I will talk about the market penetration of advanced-technology vehicles and how that might affect tax revenues. Finally I will talk about new product development, especially the efforts of vehicle manufacturers to develop clean-energy vehicles.

With regard to motor-fuel taxes and alternative-fuel vehicles, on the federal level gasoline, liquefied petroleum gas (LPG), and liquefied natural gas (LNG) sold for on-road use are taxed at $0.183/gal ($0.048/L), while diesel is taxed at $0.243/gal ($0.064/L) and compressed natural gas (CNG) is taxed at $0.058/gasoline-equivalent gal ($0.015/gasoline-equivalent L). After adjustment for the energy density of the various fuels, these translate into rates per gasoline-equivalent gallon (liter) of $0.218 ($0.058) for diesel, $0.241 ($0.064) for LNG, and $0.253 ($0.067) for LPG, compared with the gasoline rate of $0.183 ($0.048). Thus, with the exception of CNG (and ethanol, which was discussed by our earlier speaker), federal motor-fuel taxes are generally higher on alternative fuels than on gasoline.

In addition to the federal tax, each state taxes motor fuel on a somewhat different basis. Some states have vehicle fees in lieu of fuel taxes. Others waive all or a portion of the tax for ethanol or other renewable fuels. Illinois has one of the more straightforward tax structures. That is why I chose it for illustration purposes. In Illinois, LPG and LNG are taxed at roughly the same volumetric rate as gasoline [approximately $0.25/gal ($0.066/L)]. Diesel is taxed at a slightly higher rate [$0.274/gal ($0.072/L)], and CNG is taxed at a slightly lower rate [equivalent to $0.243/gal ($0.064/L)]. When converted to a rate per gasoline-equivalent gallon (liter), the diesel rate is exactly the same as gasoline [$0.246 ($0.065)], while tax rates on all other alternative fuels (again, with the exception of ethanol) are higher [$0.262 ($0.069) for CNG, $0.331 ($0.087) for LNG, and $0.347 ($0.092) for LPG]. The effect of energy density is particularly pronounced for LPG. With about 40 percent fewer Btus per gallon, an otherwise equivalent vehicle that could travel 20 mi on a gallon (8.5 km on a liter) of gasoline could go only 12 mi on a gallon (5.1 km on a liter) of LPG. However, the 12 mi on LPG would cost $0.60 in motor-fuel taxes (federal and state) versus only $0.42 for 20 mi of travel on gasoline. That is quite a discrepancy.

Baseline or "business-as-usual" forecasts of automotive fuel use generally assume little, if any, market penetration by alternative-fuel vehicles. For example, in the *2000 Annual Energy Outlook*, published by the U.S. Department of Energy's Energy Information Administration (EIA), total automotive fuel use grows by less than 1 percent per year from 1998 through 2020. Essentially all of the increase is in gasoline consumption. While automotive use of diesel and alternative fuels grows, they remain a small part of the total. However, by looking at exactly what part of EIA's alternative-fuel projection experiences the most growth, you can see that the shares held by the more highly taxed fuels (like LPG) tend to decline while those of the lower-taxed fuels (like ethanol and CNG) grow. In addition to these fuels, the shares held by electric vehicles and hybrid-electric vehicles (which generally consume gasoline or diesel fuel) also grow over time.

So in the future, revenue shortfalls could occur from increased market penetration by vehicles running on ethanol and CNG, which tend to have a more favored tax status, as well as from increased penetration by electric vehicles, which, for the most part, are exempt from motor-fuel taxes. Slower growth in LPG and LNG, both of which contribute relatively more in per-mile taxes, is not likely to offset relatively slow growth in gasoline tax revenues. With higher growth in truck fuel use, the overall rate of growth in highway tax revenues may well exceed 1 percent per year but still fall short of inflation.

For the next part of my presentation, I want to talk a little about how advanced technologies, and specifically advanced-technology vehicles, might affect fuel tax revenues. The work that I am presenting was done as part of the Partnership for a New Generation of Vehicles, a joint government-industry project to develop a vehicle that will be three times as fuel-efficient as a midsized sedan from the mid-1990s. As a point of reference, a double fuel-economy vehicle (termed 2X) would attain about 55 mi/gal (23 km/L) and a triple fuel-economy vehicle (3X) would attain about 80 mi/gal (34 km/L), all in comparison with a base vehicle with a fuel economy of 27.5 mi/gal (11.7 km/L).

Our analysis considered such issues as unit vehicle sales, the market penetration of new technologies, and vehicle utilization (since older vehicles tend to be driven fewer miles per year). We also looked at fleet dynamics, including the turnover of conventional vehicles and new-technology vehicles, recognizing that if you can accelerate the turnover of older-technology vehicles, then obviously you can improve fuel economy sooner. In fact, accelerated vehicle turnover is something that is done quite a bit in the emissions area to reduce total emissions.

How quickly can new technologies penetrate the market? For our analysis we used the market penetration of diesels in the French new-car market between 1973 and 1995 as one possibility and assumptions from the literature as indicative of another. Even under the EIA reference case, fuel economy rises from about 27.5 mi/gal (11.7 km/L) in the mid-1990s, as mentioned earlier, to 34 mi/gal (14.5 km/L) by 2030. These figures are specific to conventional automobiles only. When you add in the introduction of 2X and 3X vehicles, fleet-average fuel economy really starts to improve around 2014. At about that time the rate of increase in consumption tends toward zero, and then fuel use starts to drop off. By 2030 the combination of 2X and 3X vehicles reduces automotive fuel use by about 2 million barrels per day. Applying the federal gasoline tax rate of $0.183/gal ($0.048/L) to that figure yields about $5 billion in forgone federal tax revenues. That makes the effects of the ethanol tax subsidy look like a drop in the bucket (given the relatively slow growth in ethanol fuel use projected by EIA).

In summary, even dramatic increases in fuel economy have little effect on fuel tax revenues in the first 10 years or so. After that, however, consumption flattens and then begins to fall. By 2030, dramatic increases in fuel economy can result in significant revenue losses.

Let's now look at product development. What are these advanced vehicles that we are talking about? Today there are 97 "clean energy" models in the production, demonstration, or concept stage. Most of the production vehicles run on CNG. Many of the concept vehicles incorporate hybrid-electric technology or fuel cells. The Honda Insight, which is the first hybrid vehicle to be sold in the United States, is a small two-seater. It handles like a conventional car and but for its color would be virtually indistinguishable from any other vehicle. It gets more than 50 mi/gal (21 km/L). The Toyota Prius gets about 63 mi/gal (27 km/L). It is a full-size car and is scheduled to come on the market in fall 2000. It looks and handles like any other car.

To compete in a world market, manufacturers may have no choice. Under a voluntary agreement between the automobile industry and the European Union, European automobile makers have pledged to cut greenhouse gas emissions by 25 percent by 2008. To do so, fuel economy will have to improve by about 33 percent, assuming no changes in the carbon content of the fuel. New Japanese fuel economy standards are also on the books. When the standards are averaged over the size mix of current new-car sales, the implication is a 23 percent increase in Japanese new-car fuel economy by 2010.

In conclusion, and as I said earlier, alternative fuels have not been a key factor in motor-fuel tax revenues. With the exception of CNG and ethanol, most alternative fuels are taxed at rates higher than gasoline. Fuel-cell vehicles and, especially, hybrids are coming, but technological substitution takes a long time. For the next 20 years or so, conventional vehicles will continue to make up the bulk of the vehicle fleet. Nonetheless, highway taxes will be increasingly constrained, and in the long term, higher fuel economy will require increases in tax rates or a shift to alternative revenue sources.

A copy of the Powerpoint slides used in this presentation may be found at http://www.transportation.anl.gov/ttrdc/publications/pdfs/mintz-afv.pdf.

Alternatives to the Gas Tax

Lowell Clary

If the gas tax is going to be constrained in the future, we are going to have to look at alternatives. In my talk today I would first like to give you some idea of what the effects may be. Then I will talk about what kind of alternatives we might look at.

At the federal level, and for automobiles and gasoline only (no trucks, no diesel), an increase in fuel efficiency of 8.5 to 13 km/L (20 to 30 mi/gal) will significantly affect revenues. For example, if we are realizing gas tax receipts of $24.1 billion in 2001 at an average fuel economy of 8.5 km/L (20 mi/gal), we can anticipate that those same revenues would slide to $14.9 billion by 2010 if the average fuel economy is 17 km/L (40 mi/gal), all while holding the tax rate steady.

Now this kind of leap in fuel economy is not something we expect to happen in the near term. But it is illustrative of the fact that if you look further out, fuel economy increases could really reduce the revenues coming into the Highway Trust Fund. This is particularly true given that the revenue structure we have today is predominantly made up of fuel taxes—in fact, more than 90 percent of the receipts to the federal Highway Trust Fund derive from fuel taxes. If the gas tax is no longer going to be the source that we can depend on, what should we do? What realistic options do we have?

In assessing those options, we should look at several things. First, it is helpful if they can be construed as user fees, such that there is a measure of equity in the extent to which the amount you pay links to the extent to which you benefit. Their responsiveness to inflation is another key consideration. And the options should be assessed for stability, ease of implementation, and public acceptability.

Some vehicle-related revenue options include tolls, taxes based on vehicle miles traveled (VMT), weight-distance fees, alternative-fuels taxes, enhanced vehicle registration fees, taxes on new vehicles and parts, vehicle property fees, vehicle use fees, emission fees, and carbon or Btu or ad valorem fuel taxes. I will now discuss some of these in more detail.

Starting with tolls, of course you know that they are used quite heavily in countries across the world as well as in certain geographic areas of the United States. In Florida, current toll receipts equate to around 8 to 10 cents of gas tax on an annual basis. They can be responsive to inflation and typically are market driven because you are paying to use the facility.

A second major option is the VMT tax. There is existing technology in the form of wheel hub meters to implement this form of taxation today, but we expect even better technology in the future. The VMT tax can be equitable, and rate increases can be responsive to inflation. However, we expect that a VMT tax would require much study and education if it is to serve as a viable revenue generator.

Third, weight-distance fees are used today in the trucking industry. Again, they have the advantage of equity for all vehicles, and rate increases can be responsive to inflation. However, as you would expect, the trucking industry may have a lot to say about further implementation or expansion of this approach.

As for alternative fuels, will these come into serious play in the future? Technological advances in vehicles and associated costs will determine the speed of the transition, but to the extent that alternative fuels start to make inroads, we will need to examine the tax structure very closely. The existing structure could be applied to liquid alternative fuels, but new structures would be needed for nonliquid options.

Next, vehicle registration fees are used in many states today and could be enhanced in the future. They are easy to implement and enforce. If they are based on the price of the vehicle they are responsive to inflation, but if they are structured as a flat fee they would need to be indexed to inflation to keep pace.

Vehicle and parts sales taxes are another option. They are currently used in some states and are responsive to inflation. However, they are cyclical in nature. Parts have an inverse relationship to the economy, while sales taxes on new vehicles have a direct relationship to the strength of the economy.

Then of course we have carbon- or Btu-based taxes or ad valorem taxes. These are based on the carbon content, energy content, or value of a given fuel. They can be applied to all kinds of fuels. However, they do not reflect cost responsibility and are easy to divert away from transportation uses.

Let's now look at some non-vehicle-related revenue options, which, I should note, we see as a supplement to, not a replacement for, user fees. First, consider the leasing of air space and right-of-way. Under this model you use existing transportation assets to generate additional revenue; those leasing the facilities could include companies laying fiber-optic cable and installing telecommunications towers. If these leasing options are used on a large scale, we expect a need to resolve some significant implementation issues.

Public-private partnerships and wholly privatized transportation facilities are attracting increased interest, mostly in high-growth areas. They can add to or improve existing facilities. However, this institutional approach does not, in itself, address the bottom-line question: the primary revenue source needed to finance the construction, operations, and maintenance of the facility.

What is next? Movement in a new direction will obviously demand a shift in national policy, with state support for such changes at the federal level. Also, we need to develop implementation plans at appropriate times to ensure a smooth transition to alternative revenue sources such that we do not suffer a massive revenue loss during an interim period. We cannot let this sneak up on us.

Of course, education is essential. We believe that there must be much more study in this particular arena, including an in-depth analysis of the options and a clear plan for implementation.

Advanced-Technology Approach to Assessing User Charges: Research Progress

David Forkenbrock

So far this afternoon, we have heard that motor-fuel taxes, the mainstay of highway finance, are in serious jeopardy. In the next few minutes, I want to describe some exciting research to design and test a possible replacement to the motor-fuel tax.

This research is based on the premise that ITS technologies are very likely to play significant roles in the collection of user charges in coming years. Yet several important issues, some of which are difficult, first must be resolved. Let me begin by very briefly touching on the most fundamental principles of user-based financing for highways. I hope this discussion will provide a context for our exploration of how global positioning systems (GPS) can facilitate entirely new methods of assessing road user charges.

User charges in transportation apply pricing to what are generally public facilities. While advanced technologies have the potential to implement progressive pricing and revenue collection approaches, it is crucial to have a clear sense of one's public policy objectives. Generally, society prices public facilities for up to four reasons: to generate revenue, to cover the costs of providing service, to influence behavior to induce greater or less use of a facility, and to achieve equity or other social objectives. A flexible, modern method of assessing road user charges should enable all of these policy objectives to be pursued and, of course, should be efficient.

One key to efficient transportation finance is to recognize that the total amount of revenue generated through user charges is less important than is the revenue net of expenses incurred in collecting it. For example, for traditional toll roads it is not uncommon for administrative costs to constitute 15 to 20 percent of the revenues collected. Transaction costs, such as those associated with delays at toll collection booths, may be at least as onerous. Evasion is yet another problem that can plague user charge systems. FHWA estimates that about 15 percent of the diesel fuel tax is evaded. That is a lot of lost revenue. Finally, improved fuel efficiency and the emergence of alternative fuels provide another challenge to our current system. Moreover, once fuel cell technology reaches its potential within the next decade, the motor-fuel tax will be in real trouble.

Given the difficulties with current user or user-related charges, let's contemplate the attributes of an ideal system. They would likely include a low cost of collection for both the agency and the user; provision of a stable revenue stream; and proper cost allocation, whereby users who occasion higher costs would pay more. Other desirable attributes would include a low evasion rate and a capacity to influence users to operate on appropriate roads and to spread traffic across time periods. Finally, it would be desirable for the user charge to be unaffected by the method of vehicle propulsion.

How do we get there from here? And how well can ITS technologies help us on our way? Well, there are two fundamental ways in which ITS technologies could be applied to assess user charges: smart roads with dumb vehicles or smart vehicles with dumb roads.

Smart road technology currently is being used to collect tolls automatically. Today, more than half of the nation's 180 toll highways use electronic toll collection. But there is a major problem: smart road technology depends on roadside detectors that identify passing vehicles. The need for these detectors limits smart road technology to toll highways and perhaps urban freeways. Smart road technology is not a good bet for low-volume rural roads, city streets, or residential areas.

Smart vehicle technology has great potential for coverage of larger areas. For example, I am currently involved with a group that is designing and testing the feasibility of a flexible form of smart vehicle technology based on GPS. Our research is being funded by a special consortium of eight states (California, Iowa, Kansas, Michigan, Minnesota, Texas, Washington, and Wisconsin) and FHWA. The basic idea is to use GPS to provide real-time information about a vehicle's position; the information would be stored on board the vehicle for eventual downloading. The GPS uses a $10 billion satellite positioning and navigation system procured by the Department of Defense; there is no fee for receiving signals from this system.

Let me describe the system we are developing in more detail. A receiver on board a vehicle—either an automobile or a truck—would use GPS signals to record the vehicle's position and generate an electronic log of a trip. GPS receivers capable of providing ground positions within 100 m currently sell for less than $200; many of the larger trucking firms already use GPS technology aboard their vehicles.

Two key inputs to the onboard computer would be (*a*) GPS coordinates for the vehicle's present position and (*b*) GIS information on the road system. The computer would integrate this information, much the same way as GPS mapping features on luxury automobiles do now. In the case of trucks, the onboard computer also would merge data on the road classification with data on vehicle weight.

The result would be a complete record of road use by number of miles traveled on each road classification in each state and local jurisdiction. It would not be necessary to include information on exactly which road was traveled or on what date or time of day, reducing the potential for invasions of privacy.

Data stored in the vehicle's onboard computer would be downloaded periodically. The data-processing center to which these data are transferred would prepare billing statements and transfer revenue to jurisdictions within which the travel occurred.

For automobiles, GPS technology offers two primary public policy advantages over motor-fuel taxes. First, it is possible to charge the same per-mile rate for comparable automobiles regardless of the type of fuel they burn. We could still encourage alternative fuel use by charging a lower per-mile rate for environmentally friendly vehicles or those that are fuel-efficient. Also, marrying GPS technology to an onboard receiver that gathers information on congestion could facilitate the use of congestion pricing. This second capability is significant. Congestion pricing has been difficult to implement, even in communities where the political will may exist. The new GPS approach definitely would expedite pricing to adjust demand in gridlocked cities.

For trucks, GPS technology offers important policy advantages as well. User charges for heavy vehicles could be structured in line with the costs occasioned by these vehicles when operating on different standards of roads. Federal and state highway cost allocation studies have estimated the relative magnitudes of costs occasioned by different vehicle types operating on various classifications of roads, and these estimates could constitute the basis for the relative levels of user charges.

A key component of a GPS system for assigning user charges to heavy vehicles is an onboard vehicle weight indicator. I should note that existing pavement-based weigh-in-motion (WIM) scales that allow heavy vehicles to be weighed with minimal stopping at weigh/inspection stations would not be adequate for the GPS-based approach being discussed. First, it would not be economically feasible to install these scales along low-volume, low-standard roads. Second, even along nearly all major highways, the spacing of WIM scales would be too great to adequately record changes in vehicle weights as cargo is added or offloaded. However, new technologies are emerging that could create onboard scales that could interact with onboard data concerning the vehicle configuration. In this way, truck trailers with more axles, and that therefore impose less road damage, could be charged a lower per-mile rate.

GPS technology clearly offers promise in achieving a number of the objectives cited earlier. But if GPS is to be justified as a means for collecting road user charges, national application would be advisable and probably necessary. Numerous state legislatures would have to pass enabling legislation, and that in turn would require that a critical mass of motorists find the system not just acceptable but even desirable. Fortunately, road users would see some very real benefits from this GPS/GIS system. For example, a national system for charging truckers electronically would eliminate the myriad permits and fees now required by many states. Trucks could operate coast to coast without any administrative interruptions. Second, onboard navigation systems, already available in luxury automobiles, would become very inexpensive, perhaps under $200. Third, automatic position transmitting via cellular phone technology would enable a motorist's location to be sent to 911 in the event of a crash, health problem, or threat of crime. Fourth, the large annual registration fees assessed in some states would be replaced with a charge based on actual miles traveled. Fifth, mileage-based automobile insurance, which is already in the experimental stage, would be feasible on a broad scale. And sixth, private, high-performance tollways, akin to State Route 91 in California, would become increasingly feasible.

While the GPS-based system I just described has many advantages, there are complex public policy and technical issues that must be resolved before widespread application becomes possible. First, several limitations to GPS technology need attention. For example, when topography and tall buildings interrupt line-of-sight signals, errors can occur. Dead-reckoning capabilities during brief periods of poor signal strength may require simple analog vehicle tracking inputs to the computers on board vehicles. Second, we need to recognize that it would take a number of years for the vehicle fleet to transition to the onboard computer technology necessary for the new approach. In the interim, parallel use of the existing motor-fuel tax and the new approach would have to be fair, especially to ensure that low-income users who cannot afford to retrofit older vehicles would not be penalized.

Third, data on road use patterns must be encrypted so no one can track a person's travel behavior—while still ensuring that users would be able to dispute charges appearing on the billing statement. Fourth, it is necessary to determine how best to carry out billing. In one scenario, the download could occur each time you visit the fuel pump, with payment made on a personal credit card. For those paying for fuel with cash or driving vehicles powered by alternative propulsion systems, mail billing may be best. And finally, how would rental automobiles and NAFTA vehicles from Canada and Mexico be charged? It would be essential that any form of temporary device installed on such vehicles be virtually tamper proof.

My colleagues and I believe that all of these issues and others can be satisfactorily resolved, but we are not certain, and that is the purpose of our research. After field testing, the participating states may well determine that cost-based user charges supported by ITS technology will indeed be the centerpiece of highway finance in the 21st century. We will know a lot more in a couple of years.