The Case for Distance-Based Charging

By Jack Opiola

As the funding demand for services such as health care, education, parks, housing and social services continues to increase, the determination of an appropriate level of funding for transportation infrastructure improvement and maintenance becomes more difficult. The transport sector contrasts noticeably with other utilities where user fees collected by the utility provider are used directly to cover operating expenses and a return on investment, and where any contribution to government revenue is identified as a separate tax.

The system of financing road construction and maintenance has its origins in the common law requirement of public responsibility for road maintenance within each town, county or district. As roads became more expensive to construct and maintain following the advent of motorized vehicles, many new facilities were financed by tolls collected manually at roadside tollbooths. This system remains in place at bridges and tunnels in many countries. Manual toll collection is expensive, however, and an inefficient use of people and land, and in many cases it severely disrupts traffic flow. Consequently, it can be impractical as a means of financing a sustainable transport system.

With elaborate new toll systems cropping up around the world, it is no longer just highways, bridges or tunnels that get tolled, but entire city centers or national road networks. In 2003, London became the second major city after Singapore to charge drivers to enter the city center, an example closely watched in many other parts of the world. In 2001 and 2004 respectively, Switzerland and Austria began charging trucks nationwide; Germany and Britain will follow in 2005 and 2008. Such toll systems will almost certainly be extended to cars in the future.

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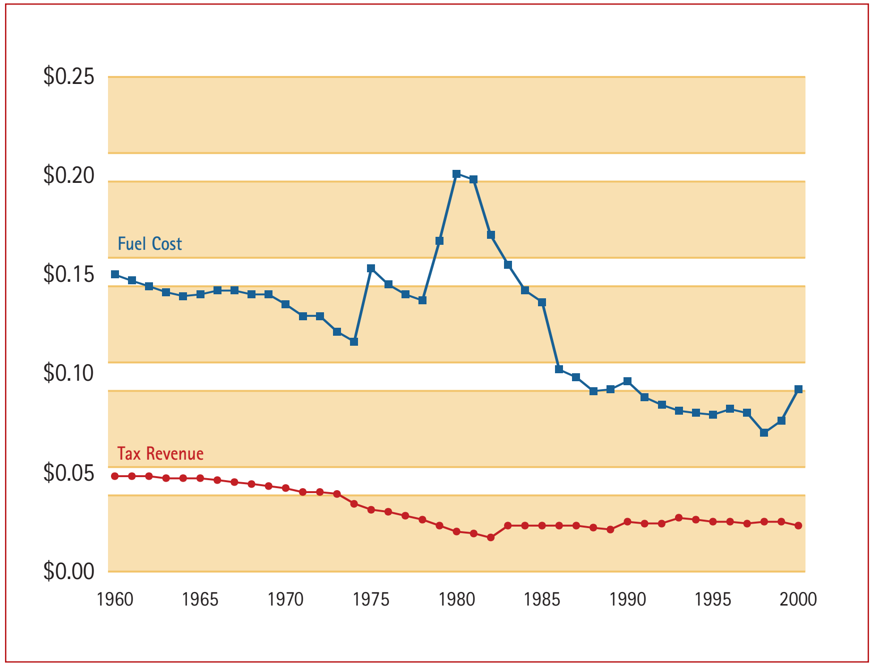
Growth of Toll Roads

Toll roads are nothing new, but the latest reach of tolling addresses a dual dilemma. First, the fountain of revenues from fuel excise taxes has begun to dry up: although there are ever more cars and ever more miles accumulated, increasingly efficient vehicles have held down tax revenues - a trend likely to continue as electric and hybrid cars become more widespread.

This is bad news for finance ministers internationally. The trend is well represented in Figure 1, which demonstrates the overall downward trend of vehicle excise tax collection in the USA.

Future projections are yet more alarming in that highly efficient vehicles will further decrease the fuel excise tax revenue by an estimated 16 to 24 percent. Governments' typical response to this declining revenue, as shown in the table, has been to increase the excise tax. In today's and future markets, however, this simply pro-

Figure 1: Tax Revenue per Vehicle-Mile in the USA



vides a greater incentive to buy a more energy-efficient car. The result is the continued downward spiral of fuel excise tax, and a fuel tax regime that increasingly targets those members of society less able to afford the newest and most efficient vehicles.

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Secondly, it is becoming more difficult and more expensive to construct roads due to environmental concerns and the rising prices of land, materials and labor. Governments therefore have little choice but to start managing demand more directly. An example of this is New Zealand's passage of the Land Transport Management Act 2003, which has heralded a new era for the planning, funding, and operation of land transport. It focuses on national policy objectives of economic development, safety and personal security, access and mobility, public health and environmental sustainability.

On the one hand, the Act creates a challenge for land-transport funders and providers to meet these objectives; but it also creates opportunities in that it allows public private/partnerships and more tolling, specifically of new roads. Estimates of how many toll roads will be created under the Act range from three to six. The first is most likely to be the road north of Auckland from Orewa to Puhoi. Transit New Zealand has announced that it intends to pursue this project as the first toll road under the Act. If funded substantially through borrowing to be repaid by tolling, this project could be completed much sooner. Transit NZ (the road builder and maintainer of the State Highways) is working with Transfund NZ (the independent funding body for transport infrastructure in NZ) and the Ministry of Transport (the national policy maker) on the requirements of a legislative act to enable the road to be tolled.

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The "Moving Forward" package announced by the government prior to passage of the Act also set up investigations of congestion or transport demand management (TDM) pricing and electronically collecting the existing road user charges for heavy vehicles and light diesel vehicles.

Additionally, the Act requires that regional councils include demand management in the development of transport strategies. Charging for infrastructure will surely play a significant role in this respect.

The Way Forward

Increasingly, direct charging for road usage seems the right solution. Tolls or road user charging obligate today's users, not future generations, to pay for transport infrastructure. They also promise to be a steadier revenue stream to supplement and even, one day, replace the petrol tax. At the same time, they have the potential to manage traffic equitably and efficiently. All this, however, requires inexpensive and proven technology. Fortunately for governments, both criteria are slowly being met, thus removing the main drawback of traditional toll roads: the high cost of constructing and operating them.

A traditional toll plaza for a two-lane highway costs up to $30 million: it requires tollbooths, an administrative building and a widening of the highway. Nearly a third of the installation's revenues are spent on operating costs, mainly in the form of salaries for toll collectors. By comparison, a state-of-the-art electronic toll plaza able to handle the same number of cars costs only about $150,000 to build and consumes only a tenth of the toll revenues in running costs.

Central to the new tolling systems are two technologies that make it much cheaper to determine whether a vehicle is in a charging zone. The first is dedicated short-range communication (DSRC), which relies on microwave or, less frequently, infrared signals. It is used in devices (such as the E-ZPass tags found in many cars internationally) that let vehicles move through a toll plaza without stopping. The battery-powered tag is activated by microwave and sends back a code identifying the vehicle. The second technology is the satellite-based global positioning system (GPS), which can deter-

Figure 2: Different Electronic Tolling Schemes Internationally

How electronic road-tolling works

London (Congestion charge)

Roadside cameras record the number plate of every vehicle within the "congestion charge" zone. Drivers pay the £5 daily charge by phone or over the internet. Non-payers are issued with fines by post.

Switzerland (LSVA)

Microwave beacons activate and deactivate each truck's on-board unit (OBU) as it enters and leaves the country. The OBU determines distance travelled from the truck's tachograph. Satellite positioning (GPS) technology is used to verify the tachograph results. Both tachograph and GPS readings are stored on a smart card. The smart card is send to the customs authority, which issues a bill.

Germany (Toll Collect)

Readings from microwave beacons, GPS, the tachograph and an on-board gyroscope are combined by the OBU to determine the truck's position. The OBU calculates the toll and informs a central data-centre via the mobile-phone network, so a bill can be issued. Roadside cameras ensure that all trucks are registered with the system.

mine a vehicle's position to within a few meters. Different designs being adopted internationally are shown in Fig. 2.

These technologies can now be more easily integrated with cameras, mobile-phone networks and other devices. The most visible expression of this is the on-board unit, or OBU – an electronic jack-of-all-trades usually installed on a truck's dashboard. Depending on the model, it can do anything from interpreting GPS and DSRC signals to reading electronic maps and transferring data to and from smart cards. In London, drivers can register via the Internet to pay the "congestion charge" for driving in the city center. The funds can then be automatically deducted from the appropriate account when a payment message is received by text message. The ability to link the web, mobile phones and the banking system makes the whole system much more efficient.

The New Zealand Case: RUC – A Simple Solution

The road user charges (RUC) system of distance/weight tax started in New Zealand in 1977. It replaced a mileage tax on diesel fuel and has evolved into the present paper-based system of pre-purchasing a distance-weight authorization for a specific class of vehicle, with distance measured via a mechanical hubodometer or odometer for light vehicles.

RUCs provide for the recovery of costs associated with road use from vehicles not taxed at source, e.g., diesel-powered vehicles. RUCs are paid in advance based on distance travelled, time on road and/or weight and axle configuration. New Zealand is one of only a few countries operating a weight/distance tax regime. It is intended to face road users with the marginal costs their vehicles impose on the road system. It has been favorably regarded by policy analysts and transport economists internationally, and it can be seen as a forerunner to the more technologically advanced schemes discussed elsewhere in this article. It gives heavy-vehicle operators positive incentives to choose axle configurations that minimize road impact, road maintenance and vehicle operating costs.

While from a technology perspective the RUC system is relatively "low-tech," it has proved the concepts of enforcement and paying for the marginal costs of road use, and is expanding to incorporate greater use of technology, such as Internet-based payments. However, in line with international developments, the Ministry of Transport is investigating electronic road user charging (eRUC), using electronic units in vehicles to replace the hubodometers, as a potentially better way of charging for road use. A feasibility study is currently being considered by government; based on early results, and functional designs emerging internationally, the system will operate as follows:

- An on-board unit (OBU) would be substituted for the hubodometer on heavy vehicles.

- This OBU would enable inputs from the driver and recording of accumulated distance travelled by either pulse generator with GPS or matching a GPS position to a digital map with agreed distances of road segments.

- Payment options and selection could potentially be very dynamic. For example, the driver could purchase road user charges (RUC) from the cab of the truck via the OBU or manually from current RUC outlets.

- Calculation of charges could be by actual weight and would have the potential to vary by road type, time of day, location and other factors. Special vehicles (oversize and overweight trucks, even vehicles carrying hazardous materials) could be monitored for compliance with defined routes.

- There would need to be a network of enforcement and monitoring sites.

- The system would be voluntary, although the existing system may become obsolete if uptake of eRUC were high.

The technology associated with such a system is being proven around the world, as discussed below.

Technology

How tolling systems are built depends partially on how a country's engineers see the world: some think a short-range approach based on DSRC is the way to go, while others bet on the global reach of GPS. More importantly, it is the national context that determines the design of a system. Is it supposed to charge for access to a city center (as in London), all roads (Switzerland) or only the highway network (Germany)?

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London's congestion-charging system was built quickly in 2002 because it was a campaign promise by Ken Livingstone, the city's newly elected mayor. As a result, the city's transport agency opted for "proven technology," in this case video image capture. Drivers pay the daily charge of £5 ($9.60) through various channels such as shops, the Internet or by phone. Enforcement is handled by nearly 700 video cameras that capture more than one million images daily of number plates within the charging zone. Each camera is connected by fiberotics to a data center where the images are checked against a registration database. Anyone who fails to pay is issued with a fine of £80 (approximately $155) by post.

In a similar concept to that adopted in London, the New Zealand government has decided to investigate road pricing on existing roads in Auckland, including an option for parking levies. This work, which began in November 2004, will cover technical evaluation costs, demand management potential, revenue potential, social, economic and environmental impact assessment, mitigation proposals and legislative implications. The purpose is to determine whether to proceed further with road pricing on existing roads and/or parking levies in Auckland.

The Swiss scheme, called the "distance-based heavy vehicles fee" (LSVA, in its German acronym) is more complex. Rather than dotting the landscape with video cameras, it uses a combination of DSRC technology, the vehicle odometer and GPS satellite signals to determine the distance each vehicle travels within the country. But the system, which currently charges transport companies between £0.11 ($0.14) and £0.45 ($0.60) per kilometer, does not incorporate the most advanced technology. A basic approach is good enough, since the task at hand is to charge for the distance driven regardless of the type of road taken (so that trucks would not switch from highways to local roads). While GPS is used, its accuracy is not essential for the system to work.

When a truck enters Switzerland, a signal from a DSRC beacon at the border station tells the OBU to start recording the distance travelled, using data from the tachograph, checked using GPS (merely as an auditing tool, because the OBU only has to determine its position intermittently). Tachograph and GPS data are saved on a smart card, which is then mailed or uploaded to the customs authority. Enforcement is done using more DSRC beacons at the roadside, and also visually. Coloured lights on the OBU tell police whether a truck is compliant.

In Austria, a more comprehensive scheme was developed exclusively for the state highways. The system is based on the DSRC technology and over 800 gantries were erected across the motorways to identify trucks using any segment of the network. These send information back to a centralized clearinghouse that bills the vehicle's account by the actual segments of the network used, the gross vehicle weight and the type of engine. The scheme went live in January 2004 and has since operated without incident.

The German system, when fully implemented, will be the most advanced thus far. Toll Collect, the firm licensed by the German government, had initial technical difficulties, but recent testing indicated near-perfect accuracy. Broader functionalities make it a much more complex system: it is foreseen as a platform for such services as fleet management, traffic alerts and navigation. Industrial policy was the main reason for pursuing this particular model: the German government wanted to help develop exportable state-of-the-art technology.

This ambitious approach guided much of the system's architecture. Toll Collect's on-board units use GPS to determine a truck's position. To compensate for the technology's weaknesses-it is only accurate to within a few meters-the device compares GPS data with information from the tachograph and a built-in gyroscope. In areas where toll-free roads parallel the autobahn, which could confuse matters, microwave beacons provide additional positioning information. The OBU is also stuffed with intelligence and electronic maps to calculate tolls. This information is sent over the mobile-phone network to a central data center, which bills truckers between 0.09 and 0.15 per kilometer. Nearly 300 cameras monitor compliance, and there are also mobile toll police to perform spot checks.

How Have the Systems Been Performing?

It is easiest to provide an answer in the German case. After much back and forth, the government and Toll Collect's owners agreed in March 2004 to launch the system in May 2005 with a stripped-down OBU, which cannot automatically update its electronic maps. The full version of the system is now projected to be functional by 2006. In testing reported in August 2004, the bugs appear to be out of the system, and independent test results suggest a system accuracy of approximately 99.96 percent with the stripped-down unit. Plans are underway to install and equip the more than one million heavy commercial vehicles in Germany.

London's anti-congestion scheme, by contrast, is an overachiever, at least in terms of traffic management. Congestion by cars in the charging zone dropped on average by 30 percent, at the high end of the original projections. Trips into the zone overall have averaged approximately an 18 percent reduction, offset by increased use of road space by buses, taxis and bicycles. The big winner appears to be public transport: buses are recording speed increases of over 20 percent and ridership has increased by more than 14 percent. Financially the project is less successful: net income is approximately £80 million – almost 40 percent less than planned. This is mainly a result of the lower number of chargeable vehicles and higher operational costs than expected. The latter has prompted a look at other technologies and it appears that DSRC is a leading candidate to supplement the existing video technology. Additionally, in November 2004, Mayor Ken Livingstone announced his intention to increase fees by 20 percent, which has raised questions in the press whether the scheme was intended to reduce congestion or create revenue.

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The Swiss and Austrian systems seem to be tremendous successes. To general surprise, both were up and running on time, and both have achieved their main objective: reducing truck traffic, which increased 7 percent during the late 1990s. In the year after the system's debut, the number of trucks on the roads fell by 5 percent. Furthermore, transport companies now try much harder to ensure that their trucks do not cross the country empty. Financially, things appear to work, too. Operating costs amount to only 6 percent of revenues, estimated at £575 million last year in Switzerland.

The Road Ahead

These initial successes do not mean that electronic-tolling schemes will take the world by storm. One barrier is common standards. The current situation is akin to the mobile-telecoms industry before the introduction of the Europe-wide GSM standard: different technologies are in use in different countries, so there is no cross-border compatibility. Although the European Union has developed technical rules, which it will soon make mandatory, it is unclear whether this will make the systems in different countries interoperable.

There are also political hurdles. Politicians will think twice before they replace a well-known revenue stream, even if it is diminishing, with a new one that might not be as plentiful as expected-as the case of London shows. But perhaps most importantly, voters may not want such systems. As well as imposing new costs on individuals, they also raise privacy concerns. Electronic tollbooths certainly allow for more control. Transport for London, the operator of the city's congestion scheme, for instance, has discovered that there are about 100 "cloned" cars – vehicles sharing identical number plates. In Switzerland, it emerged that about 20 percent of tachographs did not work properly-coincidentally, mainly those in German trucks.

If the history of comparable technologies such as the Internet or mobile phones shows, citizens eventually will put their worries aside and become consumers. Toll Collect and its shareholders did get one thing right: electronic toll-collection schemes and their underlying technologies probably will become the platform for all kinds of attractive new services, in particular when satellite-based navigation systems become more accurate.

So expect the car you buy in, say, 2020 to come with a built-in OBU, capable of charging you depending on where and when you drive and how much traffic there is. No doubt it will be able to tell you it will be rather pricey to take a certain road because it is already congested, and suggest an alternative. But it might also inform you about the nearest (and cheapest) petrol station, book your car for servicing and call an ambulance in case of an accident.

All this could have unpredictable effects. Car-insurance premiums could be charged by the mile, the kind of road and the reputation of a particular area. And local and online retailers' fortunes could improve, as shoppers start to rethink an expensive trip to a far-away shopping mall.

The OBU could even morph into a virtual backseat driver that does all these things and more, communicating with the driver using a synthetic voice, speech recognition and face-reading cameras. Microsoft recently introduced such a prototype, and big carmakers are working on similar projects. What today is merely a box to automate toll collection could tomorrow become the car's control center and communications hub.

The key for governments, however, is not the added-value services that may be possible, even if they provide consumer incentive; it is that distance-based charging, whatever the technology adopted, would supplement traditional funding sources to ensure that critical investment in transportation networks is not delayed. Distance-based charging would also allow transport policy to reflect broader social, economic and environmental objectives. Distance-based charging through electronic methods provides an efficient and cost-effective mechanism to implement an equitable and rational user-pay financing system for transport while still allowing the government to employ road pricing and other fees to effect transportation policy and raise revenues for general purposes.

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