Tolling Heavy Goods Vehicles

Overview of European Practice and Lessons from German Experience

Andrea Broaddus and Carsten Gertz

Growing road network needs, rapidly increasing truck traffic, and the shortfall of traditional funding sources have contributed to two important trends in Europe: increased reliance on user fees and involvement of private capital in transport infrastructure through public–private partnerships. Since 1995 more than 20 European countries have instituted tolls on heavy goods vehicles (HGVs) using national roadways. The motivations are several: expanding sources of revenue beyond the gas tax, managing demand for road space, encouraging efficient operations, leveling the tax burden on haulers registered in different countries, and reducing CO_2 emissions. This paper first provides a brief overview of various toll systems in use, then focuses on the German experience as a potential model for the United States. The innovative German system combines a Global Positioning System onboard unit with mobile communications technology. In its launch year, 2005, Germany collected €2.87 billion for 23.9 billion vehicle kilometers (35% by foreign trucks) tolled an average of €.12/km for autobahn use. Support of the German trucking industry was achieved through measures to increase competitiveness with foreign shippers. The toll system's first 2 years of operation indicate that avoidance traffic is a minor issue, that potential for modal shift to rail has yet to be realized, and that subsidies for clean vehicle purchase have helped reduce the pollution of the German HGV fleet.

Currently much discussion in U.S. transportation policy is devoted to the search for new or alternate sources of revenue to finance the national highway system. A recent report on highway and transit system needs from 2007 to 2017 found that existing revenue sources are inadequate, falling short of needs simply to maintain the system by $50 billion annually, and underfunding needs to improve the system by $100 billion per year (*1*). The report concluded that although fuel taxes will remain the mainstay, it is critical to develop non-fuel-based sources of financing. The fuel tax is vulnerable to inflation, to more fuel-efficient and alternate-fuel vehicles entering the fleet, and to a stubborn lack of political will to raise it. Among a menu of potential funding options, user fees such as tolls and road pricing are recommended as an increasingly feasible way to close the gap technologically and as being acceptable to the public.

Many European countries have charged tolls on their national roadway systems for decades, but an emerging trend is targeted tolls on heavy goods vehicles (HGVs). With the enlargement of the European Union (EU) since the 1990s, goods movements have significantly increased, particularly along east–west axes. Since 1995 more than 20 European countries have instituted tolls for HGVs using their national motorways. Leading the trend are those countries at the "crossroads" of Europe, where transit traffic is the most intense. Switzerland, Austria, and Germany have all instituted new electronic HGV toll systems in the past 6 years. These countries have each developed innovative intelligent transport system applications, the most ambitious of which is a satellite-based system in Germany. Their successes have spurred national and EU discussions about expanding the toll systems to include private vehicles and lower-hierarchy roads. England and the Netherlands, for example, have announced plans to implement comprehensive road-pricing schemes that may make use of the new technologies.

An accompanying European trend is toward the use of new financing structures for road building, particularly public–private partnerships (PPPs) that mobilize private capital. Many member states are finding that traditional sources of public financing fall short of huge infrastructure needs for maintenance and modernization. Reliance on user fees and concessionaire operators is increasingly the norm. In most cases, the toll system operator earns a share of the revenue stream as defined in its contract, but the government retains the power to make pricing decisions.

EUROPEAN CONTEXT

As the EU has grown, so has the disparity of road conditions, fuel prices, fees, and taxes imposed on haulers. As a result, pressure to "level the playing field" between hauling companies in different countries led to harmonization of vehicle and fuel taxes in the 1990s. First a joint HGV toll system called the eurovignette was introduced in 1995 by Germany, Belgium, the Netherlands, Luxembourg, and Denmark and Sweden. The "vignette" is a time-based permit in 24-h, week, month, or year increments displayed on the vehicle windshield. Then in 1999, an EU directive (99/62/EC) was enacted regulating HGV taxes, tolls, and charges on the entire trans-European road network (*2*). It aimed to reduce discrimination and barriers to trade by ensuring similar conditions across the internal market.

Most important, the 1999 directive set parameters for which vehicles could be tolled, and for what costs. It restricted toll charging to HGVs 12 tons or greater maximum laden weight, and only on national motorways. The formula it set for calculating toll rates allowed member states to recover the direct costs of construction, maintenance, and operations, but not externalized costs. Discounts for vehicles were permitted only on the basis of emissions class and number of axles, to prevent domestic favoritism. Member states with existing toll

Hamburg University of Technology, Institute for Transportation Planning and Logistics, P.O. Box B-9, D-21071 Hamburg, Germany. Corresponding author: A. Broaddus, andrea.broaddus@gmail.com.

Transportation Research Record: Journal of the Transportation Research Board, No. 2066, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 106–113.
DOI: 10.3141/2066-12

TABLE 1 Types of HGV Tolling Systems in Europe (*2*)

	Per Day Fee—Vignette	Per Segment Fee—Toll Plazas	Per Kilometer Fee—Free Flow
Payment	All vehicles purchase a permit sticker (vignette), attached to windshield, sold by 24 h, week, month, year	All vehicles using roadway pay at junction toll plazas, HGVs can use toll badges for electronic billing	HGVs pay for each kilometer traveled using onboard units with chip cards registered to specific vehicles for electronic billing
Technology	Windscreen sticker	Technology: DSRC[a]	Technology: DSRC, GPS, GSM[b]
Financing	Public	Financing: public and private	Financing: public and private
Operator	Public	Operator: public or concessionaire	Operator: concessionaire
Use	Revenues used for highway construction, maintenance, and operations	Revenues used for highway and rail construction, maintenance, and operations	Revenues used for transportation infrastructure
Countries	Belgium, Bulgaria, Denmark, Hungary, Lithuania, Luxembourg, Netherlands, Poland, Romania, Slovakia, Sweden, Turkey	Czech Republic, France, Greece, Italy, Portugal, Slovenia, Spain, England	Austria, Germany (autobahns) Switzerland (all roads)

[a]DSRC = dedicated short-range communication.
[b]GSM = Global System for Mobile Communications.

networks, whether time-based vignettes or distance-based, altered their fee structures to comply.

In 2006 the Eurovignette Directive was revised (06/38/EC) with several important changes. Tolls and user charges must be applied to all vehicles above 3.5 tons by 2012 and may be applied to an expanded road network, such as trunk and parallel roads (*2*). EU states are required to ensure that electronic toll systems are compatible with one another (interoperability). The directive sets fees for those states still using the eurovignette and specifies a methodology that others charging HGV fees must follow.

The 2006 directive moved in the direction of allowing member states to tailor road pricing schemes to meet policy goals beyond infrastructure finance. For instance, to encourage freight modal shift, a surcharge of up to 15% for cross financing EU priority infrastructure projects (mainly rail) was permitted. Areas with specific congestion and air pollution conditions were also allowed to charge additional fees. Some member states pushed for tolls to be calculated based on the inclusion of externalized costs, but that decision was postponed for lack of widely accepted methodology. Subsequently a topic of EU research, a toll calculation based on internalization of external costs is expected for adoption in 2008.

Tolling technology varies widely across the EU (see Table 1). Some new member states have adopted vignettes as low-cost and easy-to-implement HGV toll systems, although many plan to transition to electronic tolling soon (*2*). The directives have had a minor impact on member states with long-established toll road systems financing their national motorways. For instance, France, Italy, Spain, and Portugal toll all motorway users by road segment (at toll plazas). These operate in the same way as similar systems in the United States, such as the New Jersey turnpike. Existing infrastructure in these countries made electronic tolling for HGVs relatively low cost to implement using dedicated short range communication (DSRC). When trucks pass under gantries, onboard units (OBUs, sometimes called tags) transmit data to mounted readers, or beacon units.

A problem with "tag-and-beacon" toll systems by road segment is that in most cases HGVs are slowed by toll plazas serving vehicles without OBUs. This problem has been avoided in new "free-flow" systems installed by Austria and Switzerland, in which only HGVs are tolled, and they are required to install OBUs. These systems use gantries with DSRC units built over the roadway, allowing a free flow of traffic, as shown in Figure 1 (WAN = wide-area network). Germany also has a free-flow system, but it relies on satellites to

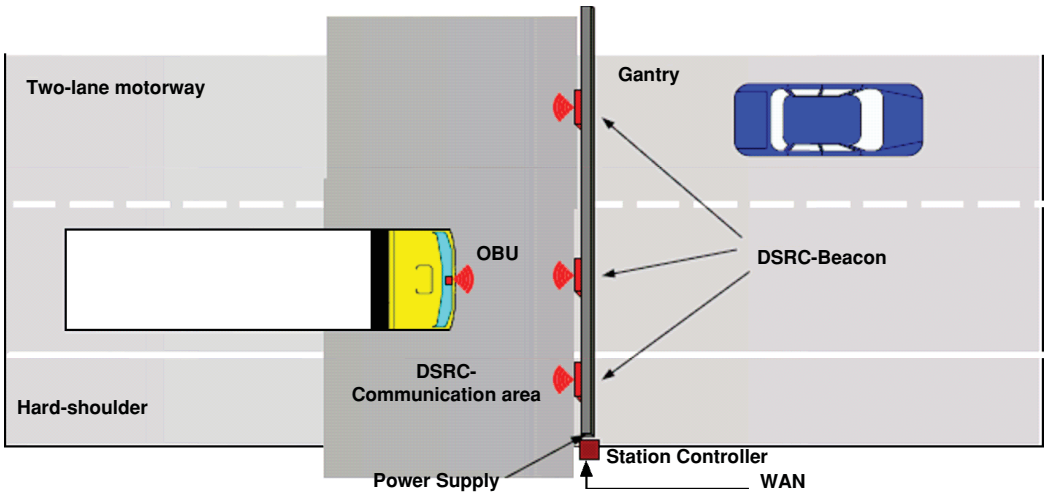

FIGURE 1 Free-flow HGV toll system using DSRC (*3*).

communicate with OBUs, using only a few gantries for enforcement purposes. The Austrian and Swiss OBUs are provided at no or low cost to haulers and are easily installed, whereas the sophisticated German OBU must be installed by a trained technician, with costs borne by the hauler. Some features of these three HGV toll systems are compared in Table 2.

HGV TOLL SYSTEMS IN SWITZERLAND AND AUSTRIA

Switzerland introduced Europe's first free-flow electronic tolling system for HGVs in 2001. Rather than for infrastructure needs, the toll was adopted in response to intense public opposition to trucks. Increasing noise and disturbance from truck traffic prompted a ballot referendum in 1994, which resulted in the passage of the Alpine Protection Article (*8*). This measure amended Switzerland's Constitution to create a moratorium on further growth of HGV traffic. It requires transport officials to limit truck traffic and shift freight to rail.

Switzerland is not a member of the EU and so is not bound by the directive limiting toll scheme charges to infrastructure cost recovery. The Swiss HGV toll rate was developed with the policy objective of limiting truck traffic and is calculated accounting for externalized costs to society. Besides infrastructure, the Swiss toll calculation includes the costs of health care, accidents, damage to buildings, and noise (*8*). The toll is applied to HGVs above 3.5 tons, and it is levied on all roadways, not just national motorways. Tolls are charged by distance and by weight on a per ton-mile basis. For instance, a 30-ton truck of emission category EURO 3 pays a rate of 2.52 Swiss centimes (€.015) per ton kilometer. For a journey of 300 km, the toll would be 2.52 × 30 tons × 300 km, or 226.80 Swiss francs (€138.16) (*8*).

The Swiss scheme had dramatic impacts. Truck traffic decreased rapidly in the first year, reversing the growth trend of HGV kilometers from 5% per year to a decrease of 5% per year (*8*). There were 77,000 (8%) fewer vehicle trips through the Alps by 2003, and these were made by larger and heavier vehicles (*8*). Evidence of a modal shift toward rail was more delayed, as infrastructure projects to expand capacity got under way with the new revenues. Although new services are now in operation, such as rail flats allowing trucks to ride "piggy back," rail has yet to gain market share.

Austria's HGV toll system on national motorways was launched in 2004, with rates set by EU policy. Personal vehicles and all others up to 3.5 tons must still purchase a vignette, and HGVs, buses, and motor homes are now required to use OBUs (*9*). These are interoperable with the Swiss system and allow pre- or postpayment of tolls.

GERMAN HGV TOLL SYSTEM

The German federal government is responsible for a road network of 53,000 km, 12,000 of which are national motorways (autobahns). In 2005 Germany introduced a distance-based toll for trucks greater than 12 tons maximum laden weight using autobahns. The toll is calculated on the basis of distance traveled, number of axles, and emissions class, based on a federal law (Motorway Toll Act for Heavy Commercial Trucks) that took effect in April 2002. The amount of the toll is regulated by the German government, currently set as shown (in euros/km) (*7*):

Emissions Class	*Three Axles*	*Four or More Axles*
EURO 5	.09	.10
EURO 3 or 4	.11	.12
EURO 0, 1, or 2 (most polluting)	.13	.14

TABLE 2 Comparison of Free-Flow HGV Tolling Systems (2005) (*4–7*)

	Austria	Germany	Switzerland
Objectives	Finance highway construction and expansion	Finance transportation construction and expansion, promote HGV efficiency	Limit HGV traffic growth and promote modal shift to rail; finance rail projects; capture externalities
Revenues used for	Federal roads (100%); 58% earmarked for underground constructions	Federal roads (50%), rail (38%), inland waterways (12%)	Federal rail network (67%), regional roads (33%)
Type of system	DSRC	GPS + GSM	DSRC + GPS + Tachograph
Roads tolled	Federal highways plus some secondary segments (142 km)	Federal highways plus some secondary segments (12,000 km)	Entire road network (71,000 km)
Average toll	€.27/km	€.12/km	€.67/km
Calculated by	Distance, axles	Distance, axles, emissions class	Distance, axles, emissions class
Payment via	OBU "Go-Box"	OBU, Internet, or roadside terminal	OBU "Tripon," or manual recording
Operator	Public–private enterprise, Europpass	Public–private enterprise, toll collect	Federal government intermodal fund, FinöV
Personnel	150 operations [ASFINAG (*9*)][a] 120 enforcement (ASFINAG)	750 operations (toll collect) 540 enforcement (BAG)	120 operations and enforcement (Swiss customs)
Capital cost	€370 million	€2.2 billion	€200 million
Operating cost	€35 million	€620 million	€35 million
HGVs tolled	> 3.5 tons	> 12 tons	> 3.5 tons
Revenues	€770 million	€2.9 billion	€800 million
Cost as % of revenue	3% capital/9% operating	7% capital/16% operating	4% capital/4% operating

[a]ASFINAG is a German acronym loosely translated as Motorways and Expressways Financing Corporation (in the sense of "public company").

Proposal and Political Coalition

Germany's road network has traditionally been free for all users. Introduction of the eurovignette for HGVs in 1995 marked the first user fee. Its success, along with a confluence of federal budget shortfalls, combined to mark the end of the free autobahn era.

Germany has become the main drive-through country since EU enlargement, meaning increased road wear and tear and traffic congestion. The Federal Ministry of Transport projected HGV traffic to grow by 70% to 83% between 1997 and 2015, mainly foreign haulers passing through Germany (*10*). Already in 2005, 35% of HGV ton kilometers were operated by foreign trucks (*10*).

Maintenance needs of the system have grown considerably since reunification with East Germany in 1991. The "degree of modernity," or ratio of net assets to gross assets, of the federal road system decreased from about 80% in the 1970s to about 70% in 2002 (*10*). Vehicle delays due to frequent road repairs and deteriorated technical conditions grew more frequent. New investments were also needed for long-existing and new postreunification bottlenecks.

The fuel tax was raised several times to keep up with system needs. There have been eight vehicle fuel tax hikes since 1991, including a 10 cent "solidarity tax" on gasoline to pay for projects in the former East. Taxes on gasoline and diesel doubled between 1991 and 2001 (*11*). Today, trucks pay a tax of €.47 per liter for diesel, and automobiles pay a tax of €.66 per liter for gasoline.

In 1999 a High Commission for Financing the Federal Transport Infrastructure was established to examine the funding problem and develop policy proposals. The Pällmann Commission, named for its chair Wilhelm Pällmann, developed a proposal to slowly convert Germany's road financing system from solely tax-based funding to usage-based charging. Its 2000 report contained several policy proposals that were later adopted by the German government (*12*).

First, the commission recommended that a new highway financing company be created that could act independently from the state and have the ability to enter into PPPs. The federal government acted to create such an independent financing company, but for all transport infrastructure, not just roads. The Verkehrsinfrastruktur-Finanzierungsgesellschaft (VIFG), or Transportation Infrastructure Financing Corporation, was established in 2003. Its primary purpose is to mobilize private capital for infrastructure investment, but there are other advantages. As a corporation, it has greater financial management flexibility than the government to transfer financial resources between fiscal years. Also, the flow of toll revenues is more transparent for users, and the VIFG guarantees that revenues are dedicated to transportation system improvements.

The Pällmann Commission also recommended a toll on HGVs. On the issue of how to set the toll rate, the commission recommended a calculation based on infrastructure cost recovery, rather than meeting traffic management goals (*12*).

The German government adopted the toll scheme proposal in 2001 with surprisingly minimal resistance from stakeholders (*10*). The general public, especially car owners, welcomed the toll as a way to reduce growing HGV traffic on autobahns. Politically, the toll scheme serves multiple policy goals and united disparate interests. At this time the German government was ruled by a "red–green coalition" (Social Democrat Party with the Green Party). Environmental groups and the Green Party embraced the toll scheme as a remedy for an underpriced public good and as a way to reduce HGV emissions through freight optimization and modal shift. Industrial and labor interests and the Social Democrat Party saw the toll system as a way to create high-tech jobs in Germany and grow market share in international freight logistics.

This political coalition helped shape the truck toll proposal. The Pällmann Commission recommended that all HGV toll proceeds should be dedicated to the road network, but the Greens succeeded in ensuring that roads receive only half the toll revenues, with the other half used for rail and inland waterway infrastructure. The Social Democrats pushed for specification of a satellite-based tolling system to be based on the EU's new satellite navigation system "Galileo" (expected in the next decade).

The main reason the trucking industry did not fight the new toll system is that it saw user fees as a way to have foreign haulers pay their fair share for Germany's roads (*10*). Foreign trucks often fuel up just across the border to avoid the high German gas tax, a practice called "tank tourism." German haulers already pay tolls in many other countries, yet struggle to compete with eastern EU firms that enjoy far lower costs for labor, fuel, and vehicle taxes, particularly Poland. Thus German firms saw the toll as a measure to level the playing field with foreign haulers, besides improving infrastructure quality and travel time reliability.

Furthermore, the German government offered domestic haulers several types of tax relief (*10*). First, the toll was reduced from the Pällmann Commission's cost coverage calculation of €.15/km on average to €.12/km, at which it remains (*10*). Vehicle taxes were lowered to the absolute allowable EU level. A subsidy program for vehicle replacement was created, incentivizing low-emission HGVs. Rebates on fuel tax expenditures were offered, deductible from toll expenses, but this was rescinded. (Germany's plan to provide €600 million in tax rebates was overruled by the European Commission as unfair discrimination against foreign haulers.)

Implementation Process

The German government decided to implement the toll scheme via PPP, and in 1999 the Federal Department of Transportation started a bidding process for its operation. After a lengthy selection and negotiations process, a contract was signed with the consortium Toll Collect in 2002. Toll Collect is a joint venture of DaimlerChrysler (45%), phone company Deutsche Telekom (45%), and French toll-road operator Cofiroute (10%). The duration of the contract is 12 years, for which time Toll Collect receives €650 million per year from HGV toll revenues (*13*). As operator, Toll Collect handles all aspects of truck toll accounting and payments to the German federal government. Toll revenues are first paid into a trust account and then forwarded to the German treasury (illustrated in Figure 2).

The contract with Toll Collect called for the toll system to be launched in August 2003, but it was delayed for nearly 2 years. The first setback was a legal challenge in European court brought by a rival consortium. Further delays were due to technical difficulties in the development process. Toll Collect was accused of delaying the launch over technical issues with value-added functions of the system, rather than its core functionality of recording toll liability. This led to the cancellation and renegotiation of the contract in 2004, resulting in lower fees and higher financial penalties for Toll Collect. Besides extralegal costs, the German government lost revenues from phasing out the eurovignette in 2003. This action turned out to be premature, allowing HGVs to use Germany's autobahns at no charge for 2 years. The delayed launch of the satellite-based toll system ultimately cost the German government more than €3 billion, which it is attempting

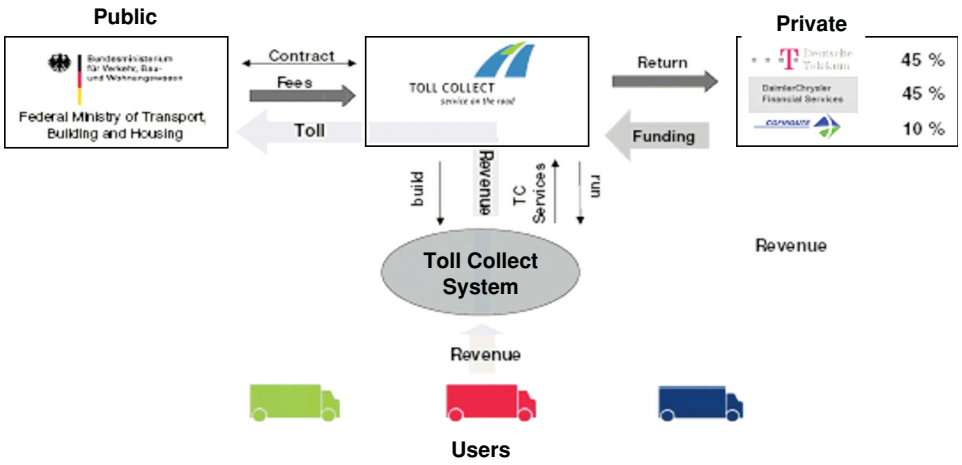

FIGURE 2 Public–private partnership model between German federal government and Toll Collect consortium (*3*).

to recover through legal arbitration (*11*). The whole debacle is known as the "Toll Collect Disaster."

How the German Toll System Works

The German toll system uses a combination of satellite navigation technology [Global Positioning System (GPS)] and mobile communications technology [Global System for Mobile Communications] (GSM), as shown in Figure 3. Most haulers equip their vehicles with an OBU that allows automatic log-on when the truck is using tolled roads. Using GPS satellite signals and other positioning sensors to detect the location of the vehicle, the OBU uses a digital map to determine the route and then calculate the distance traveled and the toll. It then transfers these data via mobile radio communication to Toll Collect for invoicing. The system automatically adjusts if the route is altered.

Not every user is required to have an OBU. Occasional users may pay the toll using the Internet or dedicated roadside terminals located at truck stops throughout Germany. Using these methods, drivers register their route and then receive a booking number as proof of payment. The system automatically calculates the shortest route.

As of January 2007 there were nearly 800,000 registered vehicles (44% non-German), 65% of which had OBUs (*13*). Roadside terminals were preferred over the Internet, with only 1% of trips booked online in 2006 (*13*).

Enforcement

Toll Collect is required by its contract to provide technical equipment and information for monitoring toll payments, but the enforcement activities are conducted by the Bundesamt für Güterverkehr (BAG), or Federal Office for Goods Transport. Several enforcement methods are in practice. There is an automated system on the autobahn network composed of 300 gantries with mounted DSRC units and cameras (trucks without OBUs are checked with plate recognition technology). A mobile fleet of 300 vehicles equipped with DSRC patrols the

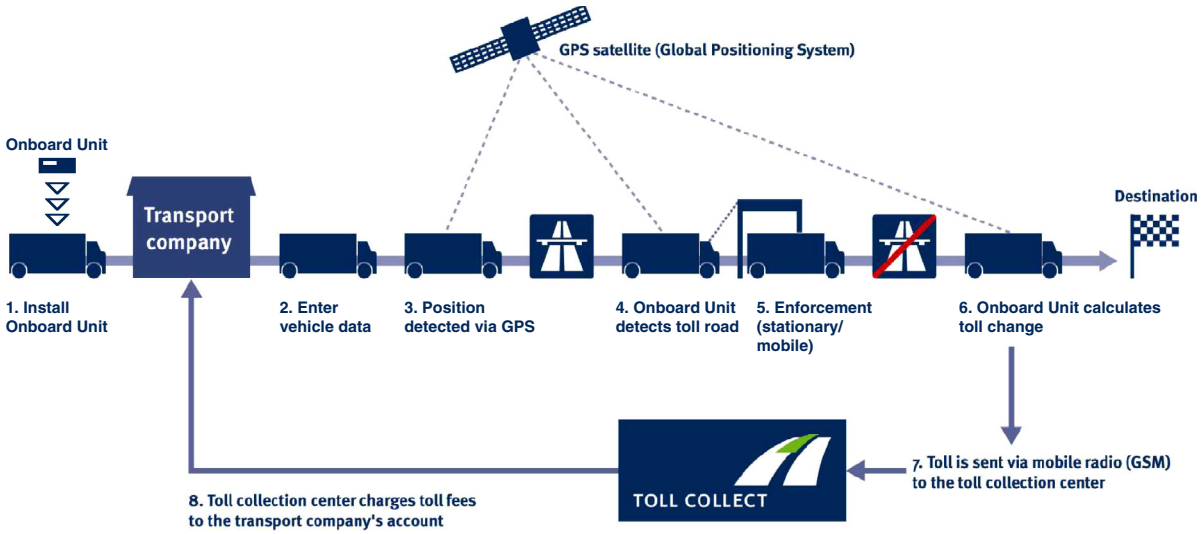

FIGURE 3 Germany's free-flow HGV toll system (*3*).

autobahns, monitoring trucks in motion. The BAG officers in these vehicles have police powers to stop and examine trucks. They conduct roadside stationary checks of roughly every 10th journey. With a motto of "no mercy for toll dodgers," system compliance was improved from 97% in its first year to 99% in 2006 (*13*). Exempt vehicles include buses and coaches.

Observed Effects

The introduction of the truck toll in Germany had immediate effects, some intended, others unintended; in some cases the consequences are not easy to determine.

The leading topic of public debate was the question of avoidance traffic, or to what extent trucks avoid toll roads and use parallel routes. Several citizen groups formed and complained about increases of truck traffic on certain routes. The Federal Department of Transportation commissioned studies of these cases using traffic counts and traffic-model estimations to assess whether countermeasures were necessary (*14*). They found that traffic grew by more than 150 trucks per day on only 5% of federal trunk roads (Bundesstrassen) and that nighttime traffic grew at twice the rate as daytime (15%), amounting to about 15 trucks per night. The impact of avoidance traffic was considered minimal, and the toll was extended to only three federal trunk roads starting January 2007.

There are several explanations for the lack of significant avoidance traffic in Germany. Many potential alternate routes are closed to trucks via traffic regulations, and most roads about which citizens complained already had a high share of trucks (*14*). German trucking firms reported they could not afford the extra time consumed by alternative toll-free routes in urban areas at peak times. This echoes research with U.S. haulers showing that delivery windows with clients are the key constraint forcing trucks to enter dense urban areas at peak times (*15*).

Avoidance traffic has been a more significant issue in neighboring countries, in which trucks can use parallel high-speed motorways to avoid toll fees. For instance, more than 500 12-ton vehicles per day were counted crossing the border from the Alsace region of France near Karlsruhe, Germany (*10*). France plans a new toll on such parallel routes to discourage spillover traffic (*2*).

Since introduction of the truck toll, there has been a clear shift in Germany toward trucks with better emission standards, partly the result of subsidies for the purchase of low-pollution vehicles (*13*). All vehicles in the EU have an emissions rating, starting from the threshold EURO 0 for the oldest and most polluting vehicles. Today, the cleanest trucks available are emissions class EURO 4 and 5. From 2005 to 2006, there were 2,700 new registrations of trucks above 12 tons in Germany, an increase of 24%. In that time frame, vehicle kilometers driven by EURO 1 and 2 class vehicles in Germany declined by about 10%, while those by EURO 3 and above grew at least that much (*13*). It is unclear to what extent this trend is attributable to the toll, to the subsidy, or to mandatory equipment replacement requirements, but the fleet change has contributed to lower vehicle emissions.

Some vehicle purchases were spurred by an effort to avoid toll fees. After the toll was announced, a number of marketing campaigns from truck manufacturers promoted HGVs just under 12 tons. Whereas in the years 1999–2002 about 4,000 vehicles between 10 and 12 tons were sold per year, the number nearly doubled to more than 7,000 vehicles in 2005, the first year of the toll. But the overall share of vehicles between 10 and 12 tons is still quite low, less than 3% of all trucks in Germany (*13*).

There has been a clear optimization effect since introduction of the toll system. Trucking firms have been able to increase their efficiency and productivity. An indicator is the share of "empty trips" made, that is, cases in which trucks make return trips without a load. Trucking firms are increasingly making use of freight exchange marketplaces on the Internet to acquire loads. Before 2005, there was a general trend of fewer empty trips, but since the toll the percentage declined sharply to 20% of trips, nearly the lowest rate in the EU (*13*). It remains unclear whether the toll is leading to an increase in load weight per trip, because smaller loads taken for return trips are trending to lower average product weight.

The toll has resulted in some increased costs to trucking firms. In most cases haulers are unable to charge their customers for empty trips. That applies especially to the food, furniture, and construction industry (*10*). BAG estimated an annual cost increase of €1,116 per truck borne by trucking firms since the toll began (*13*).

Many supporters of the HGV toll hoped it would contribute to a modal shift of freight from road to more environmentally friendly railway transportation. This potential has not yet been realized, with rail capacity constraints one explanation. There has been an increase in intermodal freight since 2005, but this is attributed to general positive economic development (*11*).

Revenues

Although Toll Collect is responsible for toll collection, the VIFG (an agency that funds traffic infrastructure) is responsible for the distribution of toll revenues collected from autobahn and inland waterway users. In 2005 Toll Collect collected €2.86 billion in gross toll revenues, which increased to €3.08 billion in 2006 (*13*). VIFG plans to spend revenues from 2006 as follows: €1.08 billion (50%) for road building and maintenance, €820 million for upgrading the federal railway network (38%), and €260 million for inland waterways (12%) (*13*).

Road-Building Concessions

One practical reason that Germany opted for a GPS-based toll system was to support a new PPP road financing model, the "A-model." The toll system can count the exact number of trips on autobahn segments, data making it possible to project HGV toll revenues and treat them like a concession. The A-model applies to the widening of existing highways. The concessionaire builds the additional lane, responsible for all aspects of construction, with the exception of design parameters. The toll transfer starts as soon as the widening is completed. The concessionaire is then responsible for the maintenance of all lanes on the widened segment for 30 years. Thus risks are shared between the contracting authority (VIFG) and the private party. VIFG keeps the risk of toll collection, plan approval, and land acquisition, and the concessionaire bears the risk of the travel volume, road maintenance and operation, and construction delays (*16*).

In May 2007 the first A-model project started with the A8 autobahn between Munich and Augsburg in Bavaria. A contract was signed with the concessionaire Autobahnplus, an international consortium of five construction and engineering companies. The total length of the road segment concession is 52 km, of which 37 km must be widened by the end of 2010 (*16*).

LESSONS LEARNED

The European trends toward user fees and public–private partnerships for road finance may point to the way for the United States. The German experience is especially instructive because of similarities between the German and U.S. road networks, which are both geographically extensive, dense, and traditionally free to users (aside from historic toll facilities in the United States). Lessons learned should aid in the development of a political strategy, identification of likely technologies, and avoidance of mistakes.

Germany, like the United States, prefers high-tech solutions that establish leadership technologically. Development of the toll system involved several influential German firms, creating jobs and intellectual property. The GPS-based OBU and its software were designed as an adaptable platform for future applications, meaning it will continue to stimulate economic activity as value-added features are developed. However, the German government's decision to develop innovative new technology rather than use proven conventional ones came with significant extra risk and costs from legal challenges and project delays, and the system's lack of compatibility with others is a delay to expansion.

Germany's toll system is considered easy to use and fair to users without OBUs. Multiple methods of toll payment and enforcement have resulted in a violation rate of less than 2%. However, these enforcement and occasional user services are personnel intensive and have proved to be significant cost drivers. The call-in booking system, for instance, is so underused that it may be phased out. The OBU has proved by far the most popular with users, which indicates it may make sense to simply require OBUs. Yet the criticism remains that the GPS-based OBUs are too expensive and should not require professional installation.

The acceptability of road pricing is dependent on a number of factors. Most important, politicians and the public must perceive an urgent need for a new approach to funding, traffic management, and environmental protection. In Germany, the twin crises of growing needs and scarcity of funds were key to building political consensus. Addressing the competitive needs of the trucking industry—making foreign trucks pay their fair share—and offering compensation were critical to building cooperation among stakeholders. Proposing road pricing as a measure to improve fairness, rather than efficiency, was more palatable to the public, as was targeting the tolls to trucks. The public may also have been more receptive to the idea of user fees because they were proposed after "maxing out" the option of raising the gas tax.

Decisions to launch the new toll system using simple parameters (only for HGVs above 12 tons and only on autobahns) and to emphasize enforcement proved wise. The system has been modified to respond to issues revealed by use patterns, for instance, the inclusion of trunk roads with a high volume of avoidance traffic and inclusion of smaller trucks. It proved to be a mistake not to phase in the launch while overlapping with the old fee system (eurovignette), because this resulted in lost revenues while neither system was in effect.

The toll system has met some policy goals better than others. It is a success in its primary goal of revenue generation. Some congestion relief from freight optimization may have occurred, but it is unclear whether more efficient use of road space is benefiting private vehicles or new HGV traffic, because HGV trips are still increasing overall. The environmental objective of reducing pollution from the German fleet has been achieved, but that of freight modal shift was negligible in the short run. This may change in the long run, because there is a lag time while rail capacity improvements are built. Germany may best reach its traffic reduction and modal shift goals by raising toll prices. For instance, Switzerland has drastically reduced truck traffic and spurred modal shift with high toll rates, which account for the externalized costs of HGV road use.

Some mistakes may serve as warnings. The challenges of developing a complex new technology for immediate full-scale launch were vastly underestimated by all parties involved, leading the project to infamy. An unrealistic, politically based schedule caused problems for the German government. Some errors were attributed to lack of experience in the German transport ministry with the magnitude of project management needs for PPPs, particularly at the precontract stage when identifying and assigning risks and verifying deliverability (*4*). The contract with Toll Collect left the government vulnerable to extra costs. For instance, it did not clearly define the scope of functional applications for delivery, leading to an overambitious development process and project delay (*11*). The government also failed to minimize risk by charging penalties for late delivery.

FUTURE OUTLOOK

The EU is continuing to expand the ability of member states to charge road user fees, with the aims of improving efficient use of the trans-European road network and reducing the environmental impacts of freight transport (*2*). HGV tolls are increasingly permitted on more roads and more vehicles and for more costs. Next steps are toward a fully interoperable, fee-harmonized comprehensive system. A 2004 directive (04/52/EC) on interoperability requires toll systems to be technologically compatible by 2010 (*2*). A directive allowing (perhaps requiring) toll rates to be calculated by internalizing external costs is expected in 2008.

The German system is not readily compatible with other systems; however it is likely to become more widely used. It is easily adaptable for any road network and forms a cost-effective solution for countries lacking toll plaza infrastructure. Several EU countries are considering a GPS-based road pricing system, including the Netherlands, England, Sweden, the Czech Republic, Slovakia, and Slovenia (*2*). The cost of the OBU is expected to fall as production scale grows, and it will be upgraded to include value-added features. Some potential applications are route navigation, dynamic traffic congestion monitoring, and infotainment. There could also be law enforcement and domestic security applications, but these raise privacy concerns.

To conclude, the situation in the United States concerning critical system needs and scarce funds is similar to challenges faced by Germany. Both countries have extensive high-speed road networks built on a public finance model and free to users—indeed, the U.S. system was modeled after Germany's in regard to those aspects. Unlike Germany, the United States has a tradition of road user fees, with several historically tolled turnpikes in the East, and decades of practice financing tunnels and bridges with concessions. Some movement toward public acceptance of road pricing is evident in recent years. Encouraged by SAFETEA-LU in 2005, several road pricing pilot projects are under way now (e.g., I-15 in San Diego, California). A few public–private partnership concession sales on existing infrastructure to finance maintenance have spurred public debate [e.g., Chicago (Illinois) Skyway Bridge]. A GPS-based pay-as-you-go system in development in Oregon may be the U.S. application most similar to the German system (*17*). Thus the question may be not whether, but when, road user fees for HGVs will be adopted in the United States.

ACKNOWLEDGMENT

The research for this report was made possible by the Alexander von Humboldt Foundation.

REFERENCES

1. Pisarski, A. E., and M. Wachs. *Future Financing Options to Meet Highway and Transit Needs.* Web-Only Document 102. NCHRP, Transportation Research Board of the National Academies, Washington, D.C., 2006. onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w102.pdf. Accessed June 25, 2007.
2. Lietchi, M., and N. Renshaw. *A Price Worth Paying, A Guide for the New EU Rules for Road Tolls for Lorries.* Report T&E 07/1. T&E—European Federation for Transport and Environment, 2007.
3. Springer, J. Toll Collect as an Enabler for New Transportation Services. Presented at Deutsches Zentrum für Luft- und Raumfahrt Galileo Workshop, March 28, 2006, Oberpfaffenhofen. www.dlr.de/kn/aktuelles/index/Galileo_Workshop/Toll_Collect.pdf. Accessed July, 20, 2007.
4. European Conference of Ministers of Transport (ECMT). *Summary and Conclusions from Conference on Road Charging Systems—Technology Choice and Cost Effectiveness,* Paris, June 1, 2006. www.cemt.org/topics/taxes/Paris06/Conclusions.pdf. Accessed July 13, 2007.
5. Viegas, J. M. et al. *Case Study Results, Analysis and Reference Scenario.* DESIRE: Designs for Interurban Road Pricing Schemes in Europe. Work Package 3. Deliverable 3. European Union Directorate–General Energy and Transport, Fourth Framework Programme Contract No. 2000-CM.10501. Brussels, Belgium, 2002.
6. Suter, S., U. Springer, A. de Palma, R. Lindsey, S. van der Loo, A. Ricci, P. Fagiani, P. Moilanen, M. van der Hooft, M. Carmona, and J. Baker. *Case Studies Specification.* REVENUE: Revenue Use From Transport Pricing. Project Deliverable 3. European Union Directorate–General Energy and Transport, Fifth Framework Programme Contract No. GMA2-2001-52011. Brussels, Belgium, 2005.
7. Toll Collect. *National Report 2006.* Presented to ASECAP Annual Meeting. www.asecap.com/english/documents/TOLLCOLLECTNATREP2007.pdf. Accessed July 28, 2007.
8. Krebs, P. *Fair and Efficient—The Distance-Related Heavy Vehicle Fee in Switzerland.* Publication 812.004.1. Federal Office for Spatial Development, Bern, Switzerland, 2004.
9. Autobahnen- und Schnellstraßen- Finanzierungs- Aktiengesellschaft (ASFINAG). *Annual Report 2006.* Vienna, Austria, 2007.
10. Wieland, B. The German HGV-Toll. *European Transport/Trasporti Europei,* Vol. 11, No. 31, Dec. 2005. pp. 118–128.
11. Rothengatter, W. New Developments in the Use of Advanced Technologies to Price the Movement of Goods in Europe. Presented at Symposium on Linking Goods Movement to Economic Prosperity and Environmental Quality, Lake Arrowhead, Calif., 2004.
12. Pällmann, W., J. Erdmenger, H. Heene, W. Junker, P. Klemmer, F.-J. Kniola, J. Lemppenau, B. Pischetsrieder, H. H. Reschke, J. Schönwasser, B. Schuchmann, and G. Vogt, *Kommission Verkehrsinfrastrukturfinanzierung Schlußbericht.* Report presented to Bundesministerium für Verkehr, Bau und Wohnungswesen on Sept. 5, 2000. www.bmvbs.de/dokumente/-,302.1957/Publikationen/dokument.htm. Accessed July 27, 2007.
13. Bundesamt für Güterverkehr (BAG). Marktbeobachtung Güterverkehr: Sonderbericht Eineinhalbjahre streckenbezogene LKW-Maut–Auswirkungen auf das deutsche Güterverkehrsgewerbe. Cologne, Germany, 2006.
14. Bundesministerium für Verkehr, Bau und Wohnungswesen. Bericht der Bundesregierung über die Verlagerungen von schweren LKW-Verkehr auf das nachgeordnete Straßennetz infolge der Einführung der LKW-Maut. Drucksache 16/298. Deutscher Bundestag. Berlin, 2005.
15. Vilain, P., and P. Wolfrom. Value Pricing and Freight Traffic. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1707,* TRB, National Research Council, Washington, D.C., 2000, pp. 64–72.
16. Bundesministerium für Verkehr, Bau und Wohnungswesen. A-Model Open Day. Presented at A-Model Open Day Symposium in Berlin, March 17, 2005. www.vifg.de/pdf/Infoday_engl.pdf. Accessed July 29, 2007.
17. Porter, J. D., D. S. Kim, H. A. Vergara, J. Whitty, J. Sadlenak, N. C. Larsen, C. B. Sexton, and D. F. Capps. Development and Performance Evaluation of a Revenue Collection System Based on Vehicle Miles Traveled. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1932,* Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 9-15.

The Trucking Industry Research Committee sponsored publication of this paper.