The Ascent of Satellite-Based Tolling Systems in Europe and Beyond

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The United States Space Program

Photo taken of the Space Shuttle “Enterprise” just after its last voyage.

Is the Space Program relevant to Mileage-Based User Fees?
What comes to mind with a photo like this?
If this a toll road, what was that rural road?
We don’t toll roads, but VEHICLES. No matter on which roads they drive on.
Fuel taxes alone cannot finance road infrastructure

Increasing need for additional road financing

- Cost of operation and maintenance of roads is growing
- Level of fuel tax revenue is decreasing
- Road users should foot the bill based on use (and abuse)
Technologies for All Electronic Toll Collection

**System description**

<table>
<thead>
<tr>
<th>Video (ANPR₁)</th>
<th>Microwave (DSRC₂)</th>
<th>Satellite (GNSS₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Infrastructural</td>
<td>On board units</td>
</tr>
<tr>
<td>description</td>
<td>based</td>
<td>with GPS,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GLONASS, GALILEO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No roadside</td>
</tr>
<tr>
<td></td>
<td></td>
<td>infrastructure.</td>
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<tr>
<td></td>
<td></td>
<td>No manual</td>
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<tr>
<td></td>
<td></td>
<td>post processing.</td>
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**Main characteristic**

- **Infrastructure based**
- **On board device necessary**
- **No road side infrastructure**
- **No manual post processing**

**Examples**

- Stockholm Congestion Tax
- London Congestion Charge
- Truck tolling schemes in A, CZ, PL
- Truck tolling schemes in D, SK, F

1) ANPR = Automatic Number Plate Recognition
2) DSRC = Dedicated Short Range Communication
3) GNSS = Global Navigation Satellite System
Siemens Plug & Play GPS On Board Unit

- Robust automotive hardware
- No connection to the odometer
- All antennas built into the device
- Secure and encrypted communication
- Integrated GSM/GPRS module
- Built-in battery
Operational Environment of the GPS On Board Unit

OBU typically has geographical data, optionally also the tariff table

Central System

Electronic Tolling Back Office (proxy)

Satellite signals 🚀 to GNSS OBU 🚗

GSM 🚗
Flexibility of the Intelligent GPS-Based OBU

- **Zone detection:**
  multiple zones, complex topology, may overlap

- **Section detection:**
  road section detection for motorways, primary roads

- **Map matching:**
  full road network detection

- **Mileage counting:**
  based on GPS

A nationwide system can easily be upgraded to include zones for city tolling
## Security Features of the Siemens GPS-Based OBU

<table>
<thead>
<tr>
<th>User opens device</th>
<th>Driving without external power connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The device is equipped with intrusion sensors.</td>
<td>• The integrated movement sensor will “wake” the device up.</td>
</tr>
<tr>
<td>• Intrusion alert is triggered, the event is stored in the log file and sent to the central system.</td>
<td>• Message about the missing power connection is stored in the log file and sent to the back office.</td>
</tr>
<tr>
<td>• Status will change to red - non operational - and the driver is not allowed to start the trip.</td>
<td>• The device is fully operational with internal power.</td>
</tr>
<tr>
<td>• Communication keys are destroyed.</td>
<td>• Optical and acoustic alarm is generated until the power connection is restored.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>User connects the device to manipulate data</th>
<th>Disruption of GPS signal through metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The service port connection uses asymmetric encryption algorithms requiring a specific key file (every single device has its own key).</td>
<td>• The integrated movement sensors will “wake” the device up.</td>
</tr>
<tr>
<td>• Any USB connection triggers an event that is stored and sent to the central system.</td>
<td>• Device can detect disturbance or manipulation of GPS signal (e.g. GPS jammer).</td>
</tr>
<tr>
<td></td>
<td>• Message about the missing or manipulated GPS signal is stored in the log file and sent to the back office.</td>
</tr>
<tr>
<td></td>
<td>• The device will display a red operational state (as opposed to green).</td>
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</table>
Puget Sound Regional Council GPS-based Pricing Pilot Project: Evaluation of Traveler Response to Variable Road Tolling

The system was in operation from July 2005 until February 2006, with over 400 GPS-based OBUs.

By the end of the study the toll system had:
- logged over 4.5 million vehicle miles traveled in trip records database
- recorded over 750,000 individual vehicle trip records on a network of 8,000 toll sections
- supported over 100,000 vehicle to central system wireless data communication transactions
- issued over 4,000 customer billing invoices

Siemens supplied the GPS Tolling Technology.
Satellite-Based Tolling Systems in Europe

Switzerland 2001: all trucks > 12 tons

Germany 2005: all trucks > 12 tons

Slovakia 2010: all trucks > 3.5 tons

France 2013: all trucks > 3.5 tons

Belgium 2014: all trucks > 3.5 tons

Because of its complex road network, Belgium is an ideal candidate for a satellite-based tolling system.

Czech Republic?

New tender of nationwide tolling planned to extend the existing microwave system (from 2007) to all major roads, using GPS.
SWITZERLAND
First Distance-Based Truck Tolling System – on all roads

Distance Measurement by Tachograph
► For Trucks > 12 tons; ~ 80,000 OBUs
► OBU Mandatory for Swiss Trucks
► Manual booking system for foreign trucks

Commercial Figures
► Initial investment costs ~ € 150 million
► Operation costs ~ 5% (use of Customs Officers)
► ~ € 1 Billion revenues generated per year

Supporting Technologies: GPS & Microwave
► GPS verifies distance, recorded on a chip-card
► Microwave for enforcement & border crossings
► OBU can also be used in Austria and in Italy

Siemens supplied the new generation OBUs
GERMANY
First Nationwide Tolling System using GPS

Section-Based Tolling System for Trucks
- Launched January 1st, 2005
- For Trucks > 12 tons; ~ 700,000 OBUs
- Entire “Autobahn” network of 12,000 km tolled

Commercial Issues
- ~ € 4 -5 Billion revenues generated per year (!)
- Operation costs ~ 15 - 20%

GPS and GSM Technologies Used
- Use of GPS proven to be highly reliable
- Dual system (manual booking) complex & costly
- > 80% of revenues generated via OBUs

Siemens supplied > 350,000 OBUs
Segment-Based Truck Tolling System

- For Trucks > 3.5 tons; ~ 220,000 OBUs
- OBU Mandatory for all trucks
- Network consists of 500km of highways and 1900 km of first class roads

Commercial Figures

- Initial investment costs ~ € 200 million
- Operation costs ~ 15%
- ~ € 150 Million revenues generated per year

Plug and Play OBU using GPS/GSM

- System built up within only 11 months
- Driver can install on windshield within minutes
- > 99% accuracy from the very beginning

Siemens supplies 2 generations of OBUs
FRANCE
Existing Toll Road Concessions
FRANCE
Nationwide Scheme for Trucks on all National Roads

French National “écotaxe”

► 15,000 kilometers of national roads which are not yet tolled
► Approximately 800,000 Satellite-based OBUs will be needed
► New operator (écomouv’) provides the GPS-service and the infrastructure
► All 5 existing toll service providers can provide the GPS-service as well
► New Hybrid-OBU must work on all existing toll-plazas (electronic lanes)
► Major challenge is the integration of the new GPS-system into the existing network of 20 tolled road network concessions (having different technologies) - INTEROPERABILITY

Siemens supplies new Hybrid OBUs to existing toll service providers
Federal Law was adopted in Russia in April 2011 that all trucks > 12 tons should pay for Federal Roads usage starting January, 1\textsuperscript{st} 2013.

This applies to approximately 50,000 km of Federal Roads.

Regional roads will probably be added: another 500,000km of roads!

There are about 1.5 million trucks > 12 tons registered in Russia; considering foreign transit trucks, about 2 million trucks will use satellite-based OBUs.

The use of GLONASS positioning technology will be mandatory – it is anticipated that a combination of GPS and GLONASS will be used.

Tender will be issued in 2012, the system could be launched by mid 2014.
Use of Three Satellite Systems for Satellite Tolling

Global Positioning System (USA)
- Uses Code-Division Multiple Access (CDMA) on 1 frequency
- Accuracy approximately 10m
- Less accurate in far north and south, in mountains, and in urban canyons

GLONASS* (Russian Federation)
- Uses Frequency Division Multiple Access (FDMA), multiple frequencies
- Accuracy approximately 10m
- Orbits at higher angle, thus much higher accuracy in the far north

GALILEO (European Union)
- Uses Code-Division Multiple Access (CDMA), on 2 frequencies
- Accuracy approximately 5m, but not until about 2016

With combined GPS/GLONASS, higher reliability and greater accuracy possible – TODAY!

* GLObal Navigation Satellite System, ГЛОбальная НАвигационная Спутниковая Система (ГЛОНАСС)
GPS and GLONASS Integrated into the Siemens OBU

A trip through Vienna’s Historical Center (urban canyons)

with a GPS-only OBU

with a GPS/GLONASS OBU
GPS: A Success Story of the Space Program

Many other countries now use GPS for tolling, why not the United States? Russia’s milestones with the first Sputnik and Yuri Gargarin’s trip into space caused the US to increase its efforts in its own space program. Now Russia is about to launch the world’s largest tolling system, using satellite technology – the toll industry in the United States should also!
Siemens Infrastructure and Cities
Electronic Tolling

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