GNSS ADOPTION FOR ROAD USER CHARGING IN EUROPE

2015

GALILEO EGNOS
NAVIGATION SOLUTIONS
POWERED BY EUROPE

European
Global Navigation
Satellite Systems
Agency

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CONTENT

GNSS OVERVIEW

WHAT IS GNSS?

Global Navigation Satellite System (GNSS) is the infrastructure that allows users with a compatible device to determine their position, velocity and local time by processing signals from satellites in space. GNSS signals are provided by a variety of satellite positioning systems, including global constellations and Satellite-Based Augmentation Systems (SBAS).

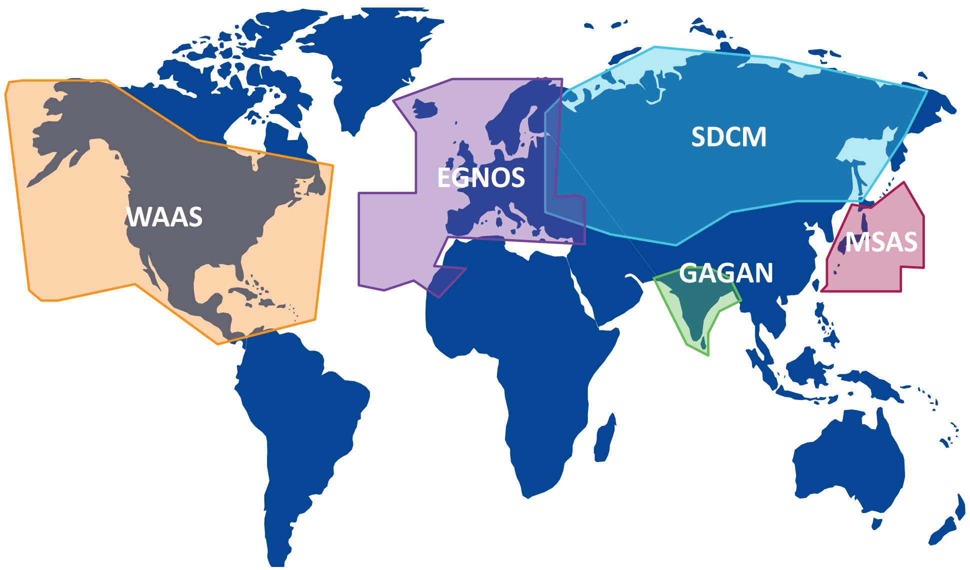
- **Global constellations:**
  - **GPS:** The first GNSS, fully operational since 1995, is managed by the US Department of Defence.
  - **GLONASS:** The Russian GNSS, completed in 1995 and fully operational since 2011, is managed by the Russian Aerospace Defence Forces.
  - **Galileo:** Europe's GNSS, currently under development as the only civil GNSS, is owned and managed by the European Union.
  - **BeiDou (COMPASS):** The Chinese GNSS, set to supersede the COMPASS regional system operating since 2000, is managed by the governmental China Satellite Navigation Office.
- **Satellite-Based Augmentation Systems (SBAS),** such as EGNOS (Europe), WAAS (North America), GAGAN (India) and MSAS (Japan).

GLOBAL CONSTELLATIONS

Global Constellations are systems of satellites that provide autonomous geo-spatial positioning with global coverage, allowing receivers to determine their location (longitude, latitude, and altitude/elevation) to high precision (within a few metres) using time signals transmitted via radio frequency from satellites. The signals allow the receivers to calculate the current local time to high precision, which allows for time synchronisation.

SATELLITE-BASED AUGMENTATION

SBAS is a method for improving the navigation system's attributes, such as accuracy, reliability and availability, through the integration of external information, sent from geostationary or geosynchronous satellites, into the calculation process.



WHAT ASPECTS OF GNSS ARE IMPORTANT?

GNSS is used for many types of applications, covering the mass market and both professional and safety-critical applications, each requiring different service levels. Depending on user needs, the important features of any GNSS include:

- **Availability:** Percentage of time the minimum number of satellites are in view, allowing the user to compute the position, navigation or timing solution requested.
- **Accuracy:** Difference between true and computed position (absolute positioning).
- **Continuity:** Ability to provide the required performances during an operation without interruption, once the operation has started.
- **Integrity:** Additional user information on the reliability of the signal within the operational requirements.
- **Robustness to spoofing and jamming:** Authentication information provided to users that ensures the signal comes from a satellite in space (thus enabling sensitive applications).
- **Indoor penetration:** Ability of a signal to penetrate inside buildings, e.g. through windows.

In the case of **Road User Charging (RUC)**, three of these features are key enablers for a robust and efficient tolling service based on GNSS: availability, accuracy and robustness to spoofing and jamming.

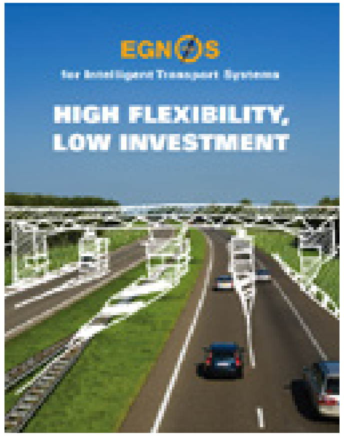
GNSS GLOBAL USERS

GNSS is used around the globe, with **3.6 bln GNSS devices** in use in 2014. By 2019, this is forecasted to increase to over 7 bln, for an average of **one device per person** on the planet.

Smartphones continue to dominate (3.08 bln in 2014), being the most popular platform to access Location-Based Services (LBS), followed by devices used for road applications (0.26 bln). Other devices may be less numerous, but billions of passengers, professionals, consumers and citizens worldwide benefit from their application across an array of sectors, from providing efficient and safe transport networks to facilitating productive and sustainable agriculture, surveying, and critical infrastructures.

At the regional level, the installed base in the mature regions of the **EU28** and **North America** will grow steadily (8% p.a.) through 2023. The primary region of global market growth will be **Asia-Pacific**, which is forecasted to grow 11% p.a., from 1.7 bln in 2014 to 4.2 bln devices in 2023 - more than the EU and North America combined. The **Middle East** and **Africa** will grow at the fastest rate (19% p.a.), but starting from a low base.

For the specific case of RUC in Europe, the GNSS market is composed today of around 1.2 million OBUs in operation and the installed base of GNSS-based RUC devices is expected to reach 3.9 million by 2020. Further details by country can be found along the next chapters of this document.

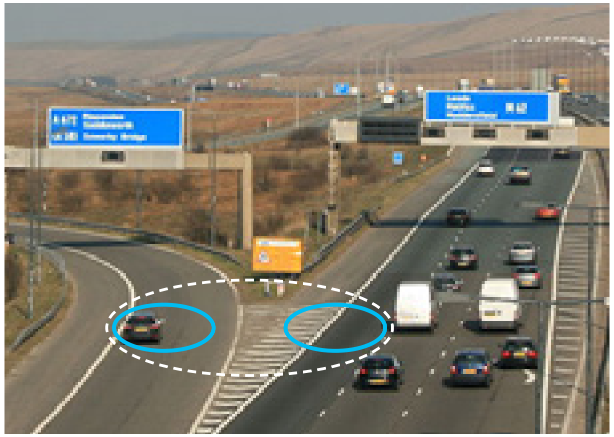


EGNOS (European Geostationary Navigation Overlay Service) is Europe's first concrete venture into satellite navigation. Essentially a 'pre-Galileo' system, EGNOS uses geostationary satellites, which transmit radio signals over European territory and North Africa. It is comprised of a network of ground stations that receive, analyse and augment GPS and, in the next version, Galileo signals.

EGNOS makes existing satellite navigation signals suitable for safety-critical and payment related applications. More so, it increases the accuracy of existing satellite positioning signals while also providing a crucial 'integrity message', informing users in the event of problems with the signal. In addition, it further transmits an extremely accurate universal time signal.

EGNOS increases the accuracy of GPS positioning by reducing the influence of ionosphere and system errors. It also provides the user with information on GPS's reliability in Europe. EGNOS provides three services:

1. **Open Service (OS):** Available free to the public for mass-market receivers and such common user applications as road tolling.
2. **Safety of Life (SoL):** For safety-critical transport applications, namely in civil aviation, this service provides enhanced and guaranteed performance and features an integrity warning system.
3. **EGNOS Data Access Service (EDAS):** To cope with higher latitudes in Europe where the reception of radio signals from geostationary satellites is challenged, EGNOS broadcasts the augmentation information over the Internet. It is offered on a controlled access basis to customers who require enhanced performance for professional use.

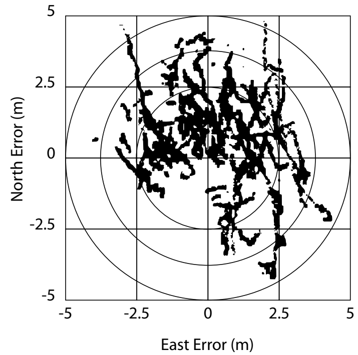


Source: ©RobChafer

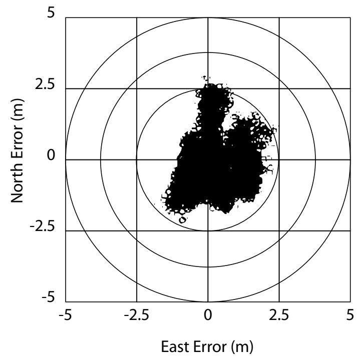
EGNOS MAKES A DIFFERENCE

Several R&D projects funded by the European Commission, using trials with real users driving in real life situations, have demonstrated the added value of EGNOS, when coupled with GPS, as an efficient tolling technology.

EGNOS



GPS



GPS + EGNOS

An EGNOS-enabled receiver can provide location accuracy to within three metres, compared to the 17-metre accuracy provided by a standard GPS-only receiver. Moreover, EGNOS provides extremely good stability over time (higher precision).

Galileo is the European GNSS under civilian control, providing standalone navigation, positioning and timing information worldwide.

With its full complement of satellites – more than any of the current GNSS systems – Galileo will allow positions to be determined more accurately. This is true even in high-rise cities, where buildings obscure signals from today's satellites. Galileo will also offer several signal enhancements, making the signal easier to track and acquire and more resistant to interference and reflections. Galileo will make possible a whole new and virtually limitless range of 'reliability-critical' services, applications and business opportunities.

Galileo will provide four basic satellite-only services to worldwide users:

- **Open Service (OS):** Free of charge for all users, featuring excellent positioning and timing performance.
- **Commercial Service (CS):** Access to two additional encrypted and guaranteed signals, delivering a higher data throughput rate and increased accuracy.
- **Public Regulated Service (PRS):** Provides position and timing to specific users who require a high continuity of service with controlled access.
- In addition, Galileo will be part of the **Medium Earth Orbit Search and Rescue (MEOSAR)** system, contributing to **Cospas-Sarsat**, the international satellite-based search and rescue distress alert detection and information distribution system.

Galileo is fully interoperable with GPS and is implemented in a step-wise approach. Twelve satellites have already been launched, with the full constellation being progressively deployed, with completion expected in 2020. However, it is **not necessary to wait for the full deployment to take advantage of the significant improvements already being offered in terms of signal availability in urban canyon environments.**

MULTI-CONSTELLATION

Galileo, in combination with other GNSS, provides improved accuracy and availability and allows for a faster time-to-fix the first position.

GALILEO AUTHENTICATION

Galileo will provide authentication services and data encryption solutions that enhance GNSS reliability and allow for the detection of attempts to spoof the signal.

MULTIPATH RESISTANT

The strength of the Galileo signal, together with an advanced code modulation, means Galileo is better able to mitigate multipath effects.

DATA-LESS SIGNAL OF GALILEO

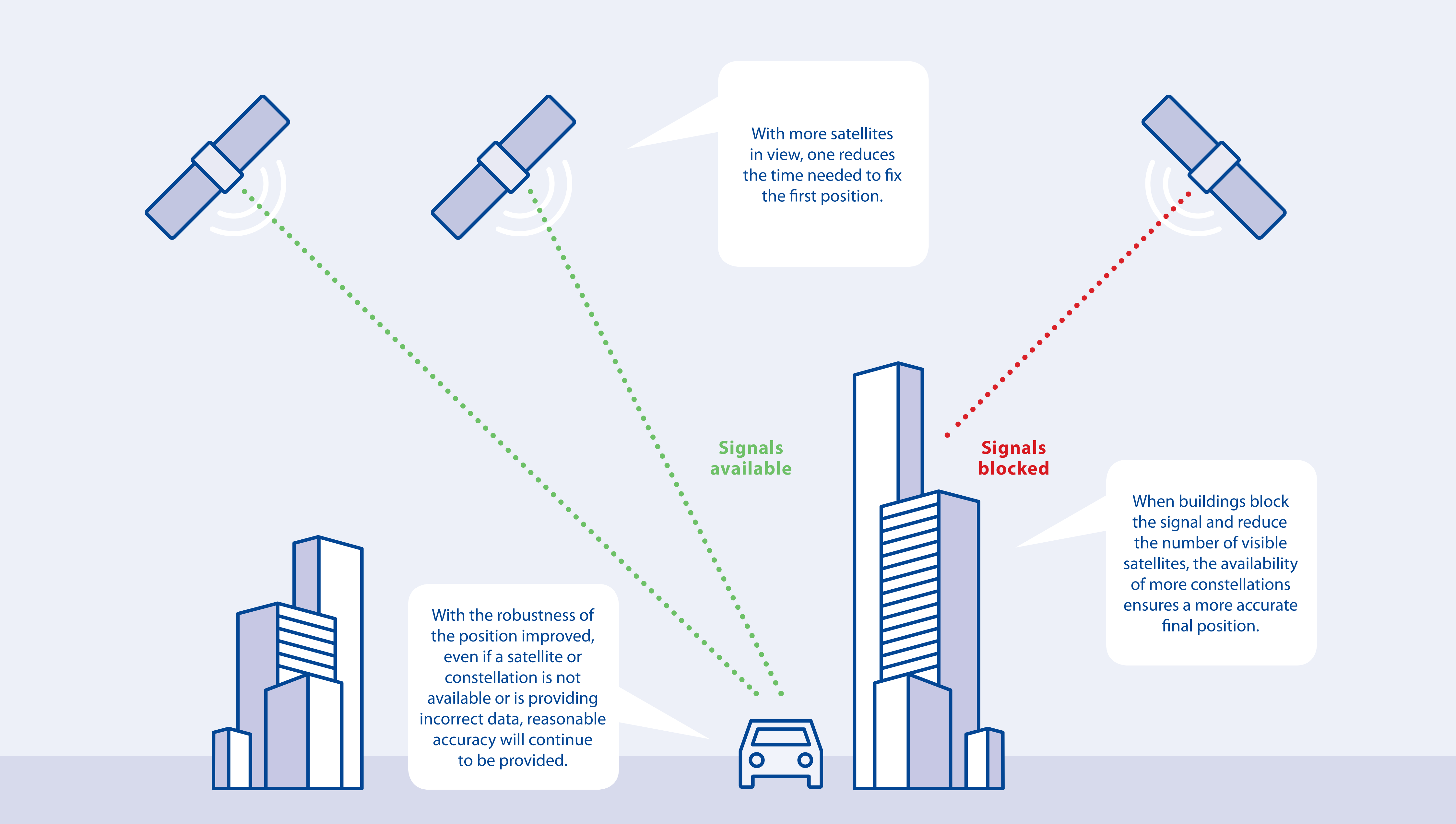
10101010
0010
0010

Galileo's data-less signal means improved performance in urban canyons, better performance in noise measurements and improved sensitivity in A-GNSS mode.

GALILEO

- Enhancement of currently offered services
- Development of new value-added applications
- More business opportunities

GALILEO: CONTRIBUTION TO MULTI-CONSTELLATION



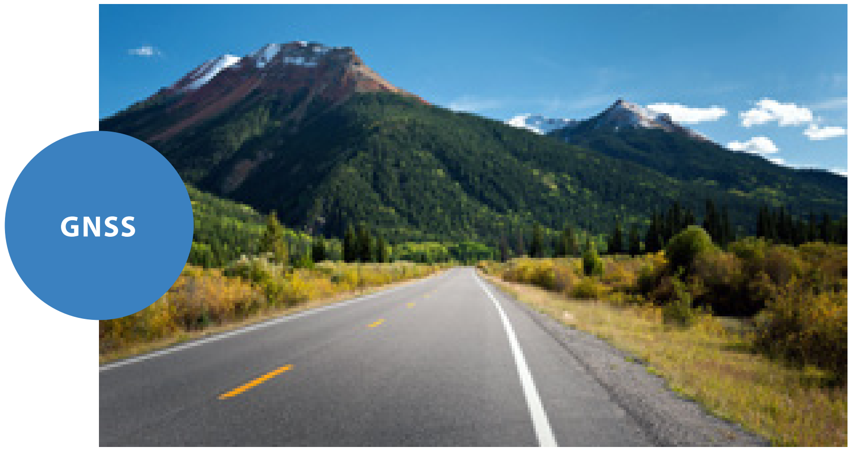
GNSS FOR ROAD USER CHARGING

Source: ©KRoock74

Source: ©Vladislav Bezrukov

GNSS is not used to toll roads. Instead, it tolls vehicles, regardless of which type or class of roads they drive on.

Source: ©JMK



Source: ©Flamouroux

LOCATION BASED CHARGING

The objective of using GNSS for Road User Charging is to charge a user (i.e., vehicle) based on its reported position. To accomplish this, several requirements must be met. First, **check point crossing detection** must be reliable in order to avoid the risk that a user's reported position triggers a charging event when it is actually in a free-of-charge position. Second, the service required to get user's actual position, thus triggering a charging event, must be **available**.

To properly determine the charge to be applied to the user, a series of steps (shown as follows and schematized on the next page) must be followed. These correspond to the workflow of a typical **"intelligent client"** approach, which can vary slightly depending on the solution vendor:

1. **Positioning:** The On-Board Unit's (OBU) integrated GNSS receiver provides information such as position, speed, orientation and degree of confidence periodically (e.g. on a second-by-second basis).
2. **Matching algorithms:** Through these algorithms, the correct road segment that the vehicle is transiting on or the virtual gantry it is passing through are identified. To do so, the required digital map has previously been downloaded to the OBU through an Over-The-Air (OTA) software update. Maps can be updated when necessary, without disruption to the service and with no effort from the user (i.e. the vehicle owner does not have to take it to a toll service provider).
3. **Toll detection:** After the matching algorithms verify that the vehicle used a road segment or passed through a virtual gantry, the toll detection process verifies whether they are part of a chargeable road network by searching on a toll object table. If the detected segment or virtual gantry are not part of a toll road network, all position data is immediately deleted, thus protecting user privacy.
4. **Rating:** If vehicles are driving on a chargeable road segment or passing through a virtual gantry, the toll charge is calculated based on tariff rules linked to the toll object. This process is called 'rating' and it generates a Charge Data Record (CDR). In this case, the position of the vehicle is not transmitted. However, for potential legal process reasons, it is stored in the OBU for a specified period of time.
5. **Transmission:** The stored CDRs are periodically reported by the vehicle's OBU to the Toll Service Provider (TSP) via a secure transmission through a Mobile Network Operator (MNO) (e.g. using GPRS, UMTS, etc.). The set of CDRs received from a particular vehicle is then processed for billing on the Back End or Central System.

Depending on the TSP and the configuration of the OBU, this process may vary. In the case a **"thin client"** approach is utilised, the matching, toll detection and rating is conducted by the central system and the coordinates (i.e. the vehicle's position) are periodically and securely transmitted by the OBU to the GNSS Proxy through the MNO. The **central system** then **matches** the vehicle's positions on a map, **detects** whether the segments or virtual gantries the vehicle has crossed are subjected to toll and **applies charges respectively**.

POSITIONING

The OBU's integrated GNSS receiver provides information on position, speed, orientation and degree of confidence.

MATCHING ALGORITHMS

The matching algorithms identify the correct road segment or virtual gantry on a digital map.

TOLL DETECTION

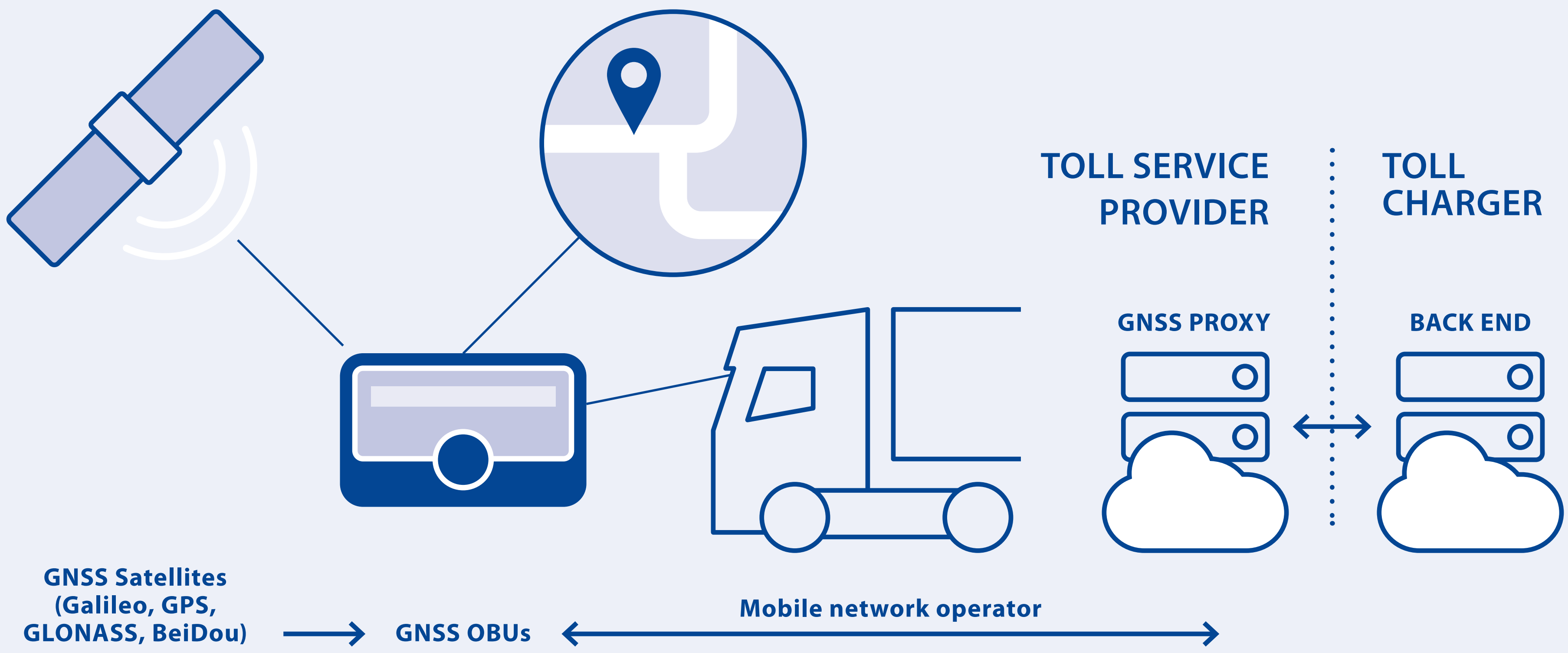
The OBU detects whether the road segment or virtual gantry are part of a chargeable road network.

RATING

Being on a chargeable segment or virtual gantry, the toll charge is calculated, creating a charge data record (CDR).

TRANSMISSION

A set of CDRs are securely transmitted to the central system for billing, from the vehicle to the TSP and subsequently to the TC.



There are diverse and substantial benefits to using GNSS for electronic toll collection, the most important being:

- **Flexibility:** GNSS can be used to charge according to different principles (time, distance, place, vehicle type, level of emissions, etc.) and can be adapted to evolving needs rapidly and cost effectively.
- **Extensibility:** It is very simple to add new sections of roads to the toll scheme, affecting only the back office system.
- **Revenue potential:** OBUs could be used as a platform for additional applications (e.g. fleet management, real time traffic information, etc.).
- **Environment and cost:** Gantries are not required for tolling, only for enforcement. This allows for around 80% less roadside infrastructure, thus minimizing the programme's environmental impact and installation costs.
- **Traffic management:** Policy-makers and road infrastructure operators could use the aggregated and anonymous data to improve traffic policies.
- **Low transaction costs:** Can be considered a cost-efficient solution in large and complex, new networks involving different vehicle categories. Already the data traffic costs from the OBU to the central system is in the order of 2€/month, and this is expected to be even lower in the short-term. New European regulations on mobile roaming will further ease the current barriers to operate abroad.

FLEXIBILITY
Rapid changes can be implemented

EXTENSIBILITY
Example of a network extension in 3 months

REVENUE POTENTIAL
SP can include several VAS to their offer

Source: Siemens AG

ENVIRONMENT (AND COST)
Around 80% less roadside infrastructure

TRAFFIC MANAGEMENT
Dynamically influence traffic behavior

LOW TRANSACTION COSTS
Data traffic costs already @ approx. 2€/month

THE EUROPEAN ELECTRONIC TOLL SERVICE

Directive 2004/52/EC and the related **Decision 2009/750/EC** aim to achieve the **interoperability of all EU electronic road toll systems**. The Directives look to avoid the proliferation of incompatible systems, which may compromise both the smooth operation of the internal market and the achievement of transport policy objectives.

The directive therefore stipulates that a **European Electronic Toll Service (EETS)** will be set up. The EETS covers all EU road networks and tolled infrastructures on which road usage is declared electronically by means of a single OBU and defines the allowed technological solutions, namely:

- **Direct Short Range Communications (DSRC)**
- **Satellite positioning coupled with mobile communications (i.e. GNSS).**

The directive does not set up EETS as such, but rather provides the framework for its establishment. Commission Decision 2009/750/EC defines EETS, inter alia by setting out the **essential requirements for interoperability**, as well as **procedural, contractual and legal aspects** relating to EETS provision.

"ONE VEHICLE, ONE CONTRACT, ONE ON-BOARD UNIT"

The EETS will enable road users to pay tolls throughout the EU with one subscription contract with one service provider and one OBU. The EETS will be available on all infrastructure with electronic tolls. It will limit cash transactions at toll stations and eliminate cumbersome procedures, thus improving traffic flow and reducing congestion.

EETS defines three main partners: the users, EETS providers and toll chargers. The EETS provider concludes contracts with users and grants them access to the EETS throughout the entire EU. The toll charger levies tolls for the circulation of vehicles in an EETS domain. Tolling policies, however, are to be decided by the Member States in compliance with EU legislation.

KEY BENEFITS OF EETS FOR ROAD USERS

- **A single contract with a single EETS provider:** This will alleviate users' administrative burden and simplify the movement of goods and people across the EU.
- **Continuous service:** No in-vehicle human intervention is required if the vehicle's toll classification parameters do not change.
- **No distraction:** Drivers will not be distracted by multiple boxes on their dashboard and they will not have to know the specificities of each electronic road toll system they come across.
- **No more queues at the toll booth:** Traditional toll-related traffic disruptions will be avoided. As a result, users will enjoy, to the benefit of the environment, more fluid and safer traffic and, ultimately, quicker journeys.
- **New or enhanced location-based services:** Satellite navigation systems, eCall with accurate caller location, route information, traffic monitoring, etc.

Source: European Commission

WHAT DOES IT MEAN FOR EETS PROVIDERS?

EETS providers, who act as an **intermediary between users and toll chargers** for the payment of tolls, can also benefit from providing additional location-based services that make use of the EETS on-board equipment.

They are entitled to approach any toll charger to obtain access to the EETS domains under this toll charger's responsibility, and they must always keep their customers informed whether their EETS subscription is valid prior to entering an EETS domain.

WHAT DOES IT MEAN FOR TOLL CHARGERS?

Toll chargers have no direct contact with EETS users, except for enforcement where necessary. They therefore no longer have to perform detailed user management and can thus concentrate on road and traffic management.

Toll chargers must publish an 'EETS domain statement' outlining the general conditions for EETS providers to access their toll domains. An EETS provider meeting these requirements should obtain access on a non-discriminatory basis, and their on-board equipment fulfilling the technical requirements will be accepted by the toll charger with whom they conclude a contract.

In addition, toll chargers have to publish the list of all the EETS providers operating on their domains and are responsible for the application of the tolling policies.

REGIONAL EUROPEAN ELECTRONIC TOLL SERVICE

The objective of the REETS project is to support existing EU legislation regarding the interoperability of electronic road toll collection. Within this framework, the project aims to deploy EETS compliant services in a cross-border regional area, including the following seven Member States: Austria, Denmark, France, Germany, Italy, Poland and Spain, as well as Switzerland (the latter without EU co-financing).

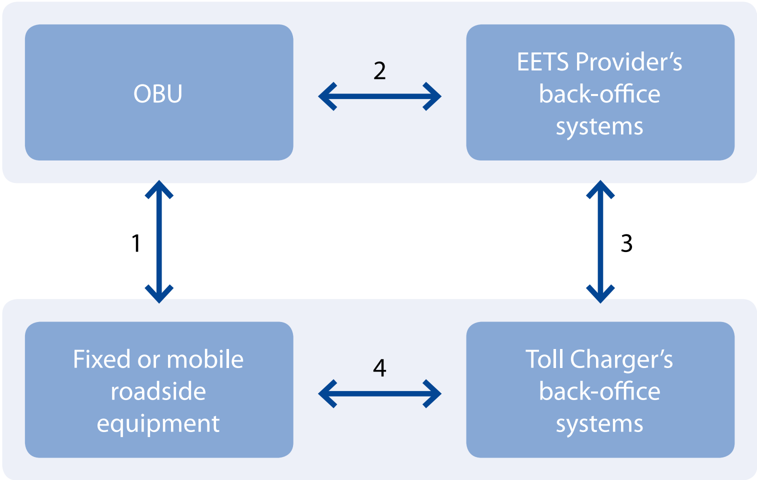
The main objectives of REETS are to:

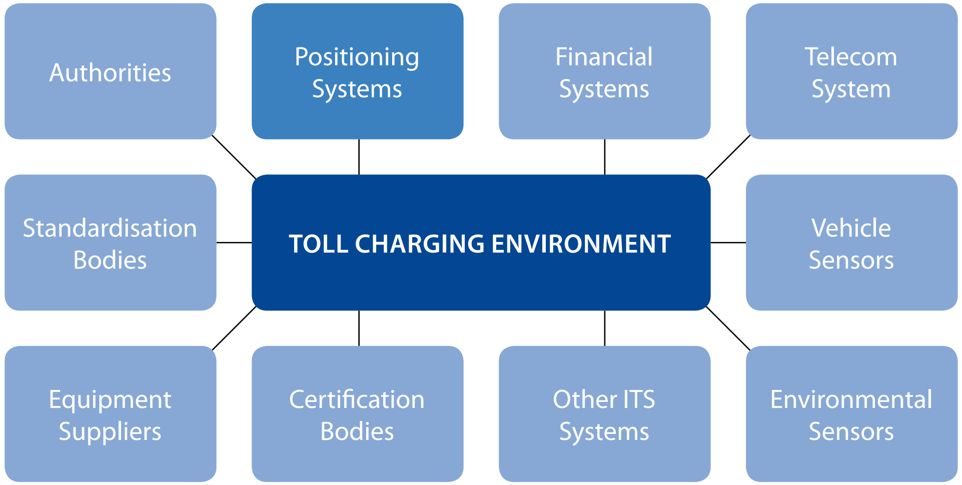
- Reduce barriers for EETS deployment by reducing business uncertainty for EETS Providers in order to prevent potential market failure of European Electronic Toll Collection (ETC) services
- Create a basis for easing the bilateral negotiations between Toll Chargers and EETS-Providers
- Develop a common understanding of the service components provided by the different roles
- Demonstrate, in practice, how EETS can be deployed and operated cross-border based on interfacing the different environments onto the results of the work packages

1. DSRC charging transactions, real-time compliance checking transactions and localisation augmentation (for GNSS-based tolling systems)
2. Remote configuration of the OBU with contract or vehicle parameters, charging data, etc. For GNSS-based toll systems, it is implemented through mobile communications.
3. Toll declaration data for submission and validation of claims for charges, invoicing/settlement, EETS blacklists, Toll Context Data, etc.
4. Charging or enforcement data from RSE to back-office systems. No application standards are currently foreseen for this interface.

In GNSS-based tolling, the role of positioning systems is to **provide the positioning services required for toll calculation**, i.e. to provide the necessary signals to determine the **time/position of a vehicle in relation to a toll domain**. Thanks to the positioning systems, toll declarations can be made, for instance, when a vehicle enters or leaves a road user charging zone or according to the distance that vehicle travelled on a tolled road network.

By using GNSS, **virtual gantries** defining toll sections are created **without the need for roadside infrastructure** beyond what is required for enforcement purposes. To date, GNSS-based schemes, in general, require gantries every 50 kilometres (enforcement only), whereas non-GNSS EETS-compatible solutions require gantries every 4 kilometres.





Source: European Commission

GNSS ROAD USER CHARGING FOR HEAVY GOODS VEHICLES

The advantages of using GNSS for tolling Heavy Goods Vehicles (HGV) have already been demonstrated and understood in Europe, and the situation is quickly evolving.

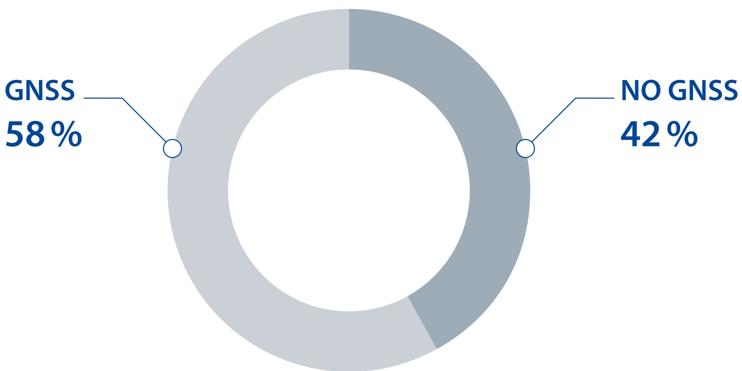
There are currently three European Member States (Germany, Hungary and Slovakia), plus non-MS Switzerland and the Russian Federation, that are using GNSS for their ETC schemes for HGV. Moreover, another system is currently under development in Belgium, which will launch in April 2016.

By analyzing only the EETS-compliant EU28 countries, i.e. those countries currently utilising DSRC (free-flow or with toll booths) and/or GNSS and excluding Eurovignette countries, before April 2016, c. 56% of the kilometres (i.e. 39,200 km) subject to toll correspond to a GNSS scheme. From 1st April 2016, in turn, the share of GNSS will raise to c. 58% since around 4,000 km of roads currently under the Eurovignette scheme in Belgium will become EETS-compliant.

If the kilometres subject to toll from Switzerland and the Russian Federation are also taken into account, from April 2016, the total length of road networks under an ETC scheme that makes use of GNSS reaches c. 165,000 km.

In the following sections, the five currently operational RUC schemes utilising GNSS, plus the in-development Belgian scheme, are defined with an overview of their key figures and most recent updates.

SHARE OF KM BY EETS TECHNOLOGY IN EU28 (FROM 2016Q2)



GERMANY

START OF ACTIVITIES

1st January 2005

TARGET VEHICLES

HGV > 7.5 ton
(from 2015 Q4)

TOTAL KILOMETRES

15,200 km
(from 2015 Q3)

TOTAL SEGMENTS

7,600
(from 2015 Q3)

REGISTERED VEHICLES

c. 900,000
(with OBU, from 2015 Q4)

TOTAL TRAFFIC

28 bln VH-km/year
(with OBU)

TOLLING INCOME

4.1 bln €/year
(with OBU)

ENFORCEMENT

1 gantry / 50 km
300 mobile units

TOLL EFFICIENCY

99.75%

The German LKW-Maut system, managed by Toll Collect, is the world's first all-GNSS truck tolling scheme, which went online in the mid 2000's. Through the course of its 10 years in operation, it has proven outstanding reliability, allowing Toll Collect to expand its contract until August 2018.

Moreover, it is the first GNSS system to provide interoperability with a DSRC-based scheme, with the Austrian ASFINAG. TOLL2GO is a joint service provided by Toll Collect and ASFINAG, which allows the truck toll to also be paid in Austria via the Toll Collect OBU. The service is especially convenient for freight transport companies with vehicles frequently on the road between Austria and Germany. Toll system customers who use the new TOLL2GO service have the advantage of only needing one in-vehicle unit (i.e. the Toll Collect OBU) to pay toll charges in both countries. ASFINAG and Toll Collect have recently extended their TOLL2GO service until the end of August 2018, in line with Toll Collect's contract extension. TOLL2GO counts c. 100,000 registered vehicles.

On 1st July 2015, toll collection began on a further 1,100 km of federal trunk roads. The preparation period lasted six and a half months, during which the new route sections were digitally recorded, modelled and checked in various testing stages. Starting at the end of May, following successful testing, the additional sections of roads were transferred through a software update via mobile radio to approximately 850,000 OBU, which automatically downloaded the information.

Moreover, on 1st October 2015, the LKW-Maut's scope was extended to include trucks from 7.5 tonnes.

It is expected that the expansion of the tolled highway network will add another 500M € of annual revenue. More so, the annexation of trucks from 7.5 tonnes will account for c. 80,000 more vehicles, adding another 200M € and rising the number of OBUs to c. 900,000.

Currently, most of Toll Collect's OBUs support EGNOS and from 2015, one of the OBU providers has included a Galileo-enabled chipset for a more robust positioning determination.

Source: Toll Collect

HUNGARY

START OF ACTIVITIES
1st July 2013

TARGET VEHICLES
HGV > 3.5 ton

TOTAL KILOMETRES
6,500+ km

TOTAL SEGMENTS
N/A

REGISTERED VEHICLES
380,000
(86,000 with OBU)

TOTAL TRAFFIC
2.47 bln VH-km/year

TOLLING INCOME
286 mln €
(2015 H1)

ENFORCEMENT
1 gantry/88 km
100 mobile units

TOLL EFFICIENCY
N/A

The launch of the Hungarian HU-GO system, managed by National Toll Payment Services PLC (NTPS), was an important step towards open RUC schemes, which subsequently led to innovative value-added services with respect to other GNSS-based RUC solutions present in the market (e.g. fine alert service when non-compliance is detected, mobile application for ticket purchasing and vehicle data update, etc.).

While in other countries it is only possible to use the automatic tolling service through a single, central company, in Hungary small and medium enterprises (SME) and companies with fleets of vehicles can use the system on a market basis and as reporting contributors. In this sense, in 2015, the list of Audited Toll Declaration Operators (TDO) showed 22, and the list of companies that can install the OBU but whose devices cannot be used for the tolling scheme was 18. The conditions that TDOs have to comply with, from the accuracy of declaration standpoint, are at least 94% accuracy within 15 minutes, 99,94% accuracy after five days and 100% accuracy after 25 days.

Although relying solely on GPS, the results are satisfactory for NTPS purposes and there have been only minor issues related to inadequate tolling. However, an important provider of robust GNSS-based OBUs tested its equipment and obtained an outstanding 99.8% accurate reporting within 15 minutes with an EGNSS-enabled OBU. Considering that 1000+ penalties are issued per month due to incorrect declarations, the company is now offering its OBU through an audited TDO.

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HU-GO

NATIONAL TOLL PAYMENT SERVICES PLC

OPEN SYSTEM

Allows local and foreign SMEs to participate

VERY RAPID DEPLOYMENT

Allowed for a 3-month return on investment (ROI)

THIN CLIENT APPROACH

Server side processing allows for fast development of several value-added services

SLOVAKIA

START OF ACTIVITIES
1st January 2010

TARGET VEHICLES
HGV > 3.5 ton

TOTAL KILOMETRES
17,763 km

TOTAL SEGMENTS
4,294 segments

REGISTERED VEHICLES
246,900
(with OBU)

TOTAL TRAFFIC
35,000 daily vehicles

TOLLING INCOME
190 mln €/year
(38% 1st class roads)

ENFORCEMENT
1 gantry/378 km
30 mobile units

TOLL EFFICIENCY
99.84 %
(since first year of adoption)

As of 1st January 2014, Slovakia's Skytoll system added additional 1st, 2nd and 3rd class roads to the charged network, expanding the total chargeable road network to:

- **658 km of motorways and expressways**, all charged with "non-zero tariffs"
- **3,625 km of 1st class roads**, most (c. 2,600 km) charged with "non-zero tariffs"
- **13,479 km of 2nd and 3rd class roads**, all charged with "zero tariffs"

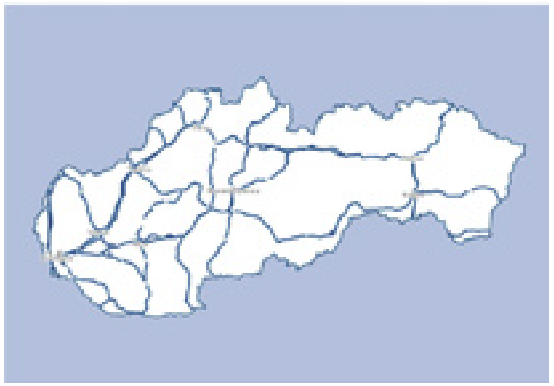
The decision to add 2nd and 3rd class roads to the toll system was in response to a request from the National Motorway Company to obtain information about the density of lorries over 3.5 tonnes on these roads. This information is important for better planning the next steps of charging and to better allocate resources for the repair or construction of new roads based on accurate traffic congestion data. This information, owned by SkyToll, may be used by other entities, such as customs officers to detect fake exports abroad and the related tax evasion.

Preparing the enlargement of road pricing (i.e. 15,000+ km) in Slovakia lasted just three months and the actual start of the extension only required a few hours to upgrade the OBU software (i.e. a new geomodel) using an over-the-air upgrade.

All of SkyToll's OBUs support EGNOS and nearly 20% include a Galileo-enabled chipset for a more robust positioning determination.

UNTIL 31/12/2013

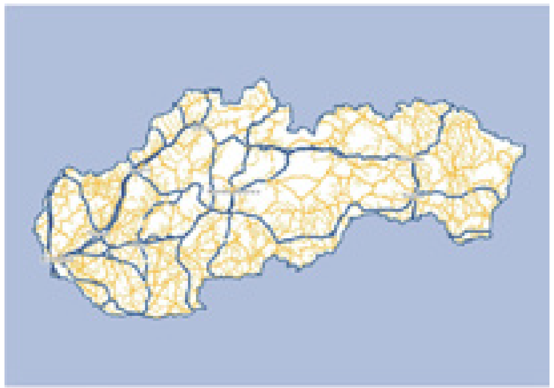
2,447 KM
1,132 SEGMENTS
0 KM URBAN CHARGED



Source: SkyToll

FROM 01/02/2014

17,763 KM
4,294 SEGMENTS
985 KM URBAN ROADS



Source: SkyToll

RUSSIAN FEDERATION

START OF ACTIVITIES

15th November 2015

TARGET VEHICLES

HGV > 12 ton

TOTAL KILOMETRES

50,774 km

TOTAL SEGMENTS

N/A

REGISTERED VEHICLES

2 mln
(with OBU, expected)

TOTAL TRAFFIC

N/A

TOLLING INCOME

0.9 bln €/year
(expected)

ENFORCEMENT

1 gantry/105 km
100 mobile units

TOLL EFFICIENCY

N/A

The Russian Platon RUC system has been developed by "RT-invest Transportation Systems", a subsidiary of Rostec, which acts as sole concessionaire. It collects toll charges from HGV with the aim of offsetting the damage such vehicles cause to road surfaces. The Russian Federal Budget then invest the revenues to fund road maintenance and repairs, as well as general road network improvements.

The project helps achieve the goals set out in the subprogramme "Roads" of the Russian Federal Transport System Action Programme for 2010-2020. Not only will it ease the pressure on public funds, but will also serve to further improve the state of Russian federal highways.

While charges to vehicles weighing more than 3.5 tonnes relate to future objectives, the Ministry of Transport, in conjunction with Rostec, are assessing the feasibility of tolling this category of vehicles.

MegaFon, one of the largest mobile operators in Russia, has been contracted to provide machine-to-machine (M2M) services for RT-Invest Transport Systems by supplying up to two million SIM cards for OBUs that will be installed in HGVs by 2017.

The OBU uses GLONASS and GPS to geo-locate the vehicle, with the coordinates sent to the data processing centre through GSM/GPRS mobile operators' networks. The system is then based on a thin client approach, where the matching algorithms, toll detection and rating is conducted by the central system.

Source: Platon.ru

РТ-ИНВЕСТ
ТРАНСПОРТНЫЕ СИСТЕМЫ[1]

1. RT-Invest – Transportation Systems

SWITZERLAND

START OF ACTIVITIES

1st January 2001

TARGET VEHICLES

HGV > 3.5 ton

TOTAL KILOMETRES

71,500 km
(c. 1,800 km of motorways)

TOTAL SEGMENTS

N/A

REGISTERED VEHICLES

55,000 (domestic)
3,000 (foreign)

TOTAL TRAFFIC

N/A

TOLLING INCOME

1.42 bln €
(in 2014)

ENFORCEMENT

25 gantries (at borders),
100 mobile units

TOLL EFFICIENCY

N/A

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Even if it is not GNSS-based, the Swiss RUC scheme was the first to use GNSS to monitor the recording of mileage performed by the tachometer, as well as to determine whether the unit is in Switzerland or abroad.

For vehicles registered in Switzerland, it is mandatory to use the OBU that determines the exact mileage based on the signal transmitted by the tachometer. Foreign vehicles use an ID card and a special terminal at each entry where they can personally declare their mileage driven.

The rollout of a second generation of OBUs was concluded in 2012. The Emotach has been installed in all HGV vehicles circulating in Switzerland during regular workshop visits, with the cost covered by the operator. Emotach is compatible with the Austrian (ASFINAG) and Italian (Telepass) systems.

After more than a decade in use, the benefits of using a GNSS-supported system have been significant for Switzerland. During this time the RUC scheme has demonstrated that:

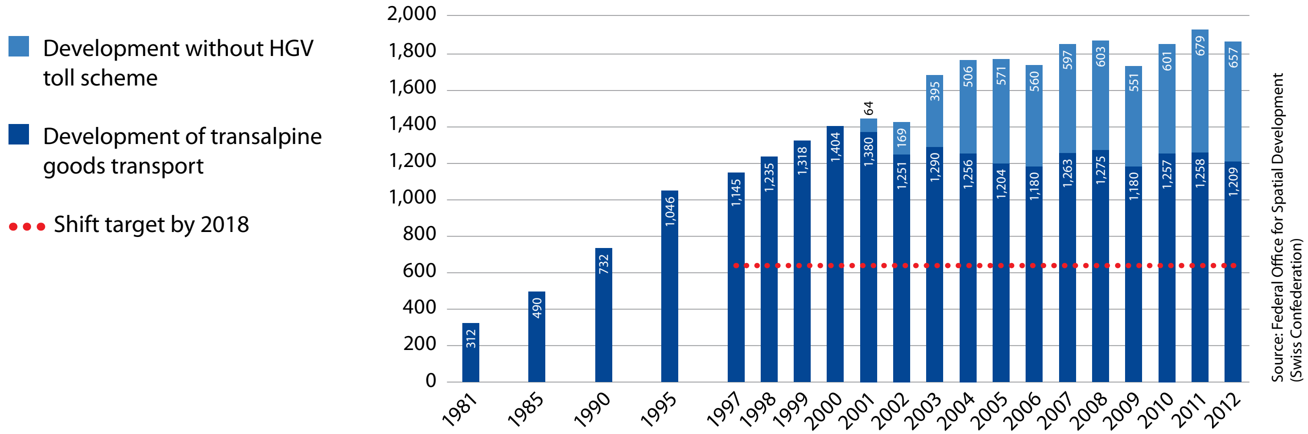
- The system works well and it has **low operational costs (5% of revenue)**
- **Truck traffic has been reduced**, with a positive balance for the environment
- **Road transport has become more efficient**, with a fee equal to about 20% of costs, but outbalanced by productivity gains (e.g. higher weight limit and less empty trips)
- The **impact on the final customer price has been negligible**, with transport costs being, on average, only 1-2% of the final price and the impact on inflation being only 0.11% (according to Swiss Federal Office for Statistics)
- **The railway system has maintained a high market share** (40% overall and 65% in transalpine transport)

With the RUC scheme, the primary objective of reducing the transit of HGV in the Swiss transalpine corridors has been achieved from the first year of operation, eliminating its tendency to increase year-on-year.

Source: © Larag

Transalpine goods transport through HGV

Observed development and estimated development without RUC scheme



BELGIUM

START OF ACTIVITIES

1st April 2016

TARGET VEHICLES

HGV > 3.5 ton

TOTAL KILOMETRES

4,000 km

TOTAL SEGMENTS

N/A

REGISTERED VEHICLES

700,000
(78% foreign, expected)

TOTAL TRAFFIC

N/A

TOLLING INCOME

800 mln €
(expected)

ENFORCEMENT

1 gantry/64 km
40 mobile units

TOLL EFFICIENCY

N/A

The Belgian Viapass system is currently under development and will start operations on 1st April 2016. Managed by Satellic NV, the programme will collect tolls on behalf of the Flemish, Walloon and Brussels-Capital regions.

The toll will be levied on motorways and a number of regional and municipal roads. The OBU must be switched on whenever using a Belgian road. The system is based on the 'user pays' principle, meaning that everyone pays a fair contribution for using the roads.

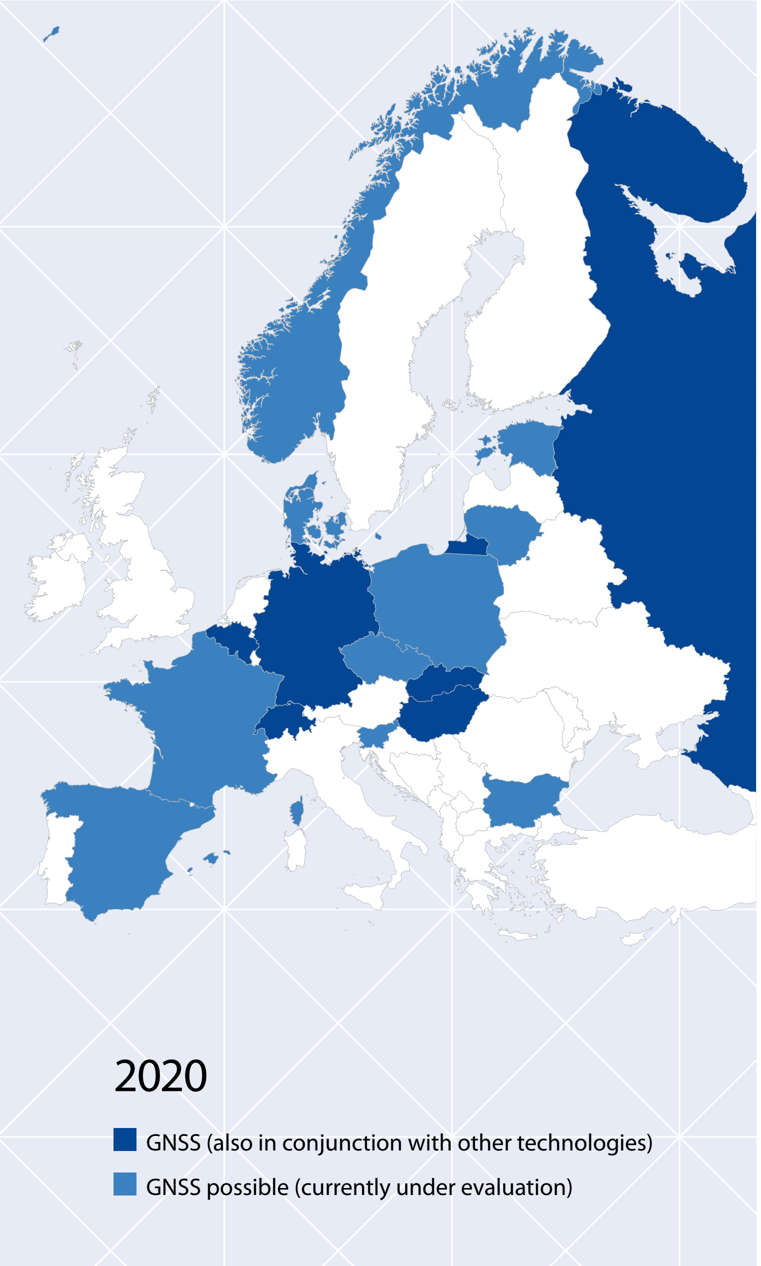
Although the OBUs, which will be EGNSS-enabled from the start, will be mandatory, they will not be paid for by the users. Instead, a guarantee deposit (i.e. 135 €) will be required, reimbursable upon the return of the undamaged OBU.

The maps and tariffs are already published on the Viapass website, and the system will be "EETS Ready" to allow other EETS providers to offer their services in Viapass' Toll Domains. In light of this, Viapass has organised EETS update briefings to provide information for the configuration of the infrastructure and OBU's before the system goes live.

In August 2015, with the publication of the decree and ordonnance in the official Gazette, the Belgian kilometre charge has been officially introduced in the three regions (i.e. Brussels, Flanders and Wallonia).

A remarkable aspect of the Belgian scheme is the political support given by the three regions, essential to achieving public acceptance. One of the key messages to the user community has been that revenues will actually enhance the country's transport conditions.

Source: © Satellic



BULGARIA

Bulgaria has plans to introduce a road tolling scheme in 2018 and the Road Infrastructure Administration has contracted the World Bank to define a strategy for the implementation of an EETS-compatible system.

The World Bank[1] has concluded that a GNSS-based system suits best the requirement to toll all motorways and certain 1st and 2nd class roads. The proposed method is similar to the one used in Hungary for HU-GO, where existing GNSS technology such as fleet management systems is used to report the position of the vehicle to the TSP. More so, the system must be interoperable, flexible to meet future needs and unimpeded upgrade, user friendly to gain public acceptance and must assist Bulgaria meet its security obligations and the fight against crime.

CZECH REPUBLIC

In 2014, the incoming Minister of Transport added the task of choosing the next TSP contractor to the agenda. In December 2014, a political proposal was presented to lower the number of truck drivers tempted to avoid travelling on toll-subject segments by making them pay a fine of up to 730 € and docking two points from their licence. As in the case of Bulgaria, for this latter requirement, a country-wide control is necessary, for which GNSS seems to be the only viable solution.

More recently, the Minister of Transport has engaged the services of an international consulting firm to prepare the tender for a new, three year contract. The shorter duration is a result of plans for an upgraded RUC scheme, potentially integrating new roads and GNSS based charging – topics currently in high-level discussions.

1. Bulgaria: Development of a comprehensive vision for the introduction of the electronic system for provision of the EETS. The World Bank and Bulgaria Road Infrastructure Agency, October 2015.

DENMARK

Looking to obtain knowledge and experience in the use of GNSS technology, Sund & Bælt, the state-owned limited company managing the Øresund motorway and the Storebælt bridge, is conducting a trial in the Greater Copenhagen Area. The company notes that it is important to look towards both interoperability in Europe and to other possible RUC scenarios, such as a toll ring or national road pricing.

The tender on "Research and development services and related consultancy services" for these trials was published on 24 March 2015, and two companies were selected for the testing.

ESTONIA

The Estonian Road Administration is conducting studies on the possible introduction of an ETC for trucks. As of 2015, an international consulting firm has been supporting the government on the feasibility analysis, the results of which are not yet available.

FRANCE

Although the Ecotaxe, the French HGV toll scheme, was completely cancelled at the end of 2014, some regional representatives have asked for the utilisation of the already installed infrastructure in northern France, stating it would be a natural extension of the Belgian ETC system.

However, the national government seems to have no plans to revive the Ecotaxe, as it is ready to launch an HGV vignette for the entire national and county road network not currently conceded.

LITHUANIA

The Lithuanian Road Administration has contracted with an important international consultancy company to conduct a feasibility study on the implementation of an ETC system. Part of this study involves estimating investments and costs for serving c. 2,400 km of roads "of national significance" with DSRC- or GNSS-based solutions.

Moreover, in May 2015, and in just 15 days time, SkyToll implemented an electronic toll collection solution on 353 kilometres of motorways, national and regional roads with a total of 309 road sections. This project was within the framework of the Lithuanian Ministry of Transport and Communication and aimed to showcase the benefits of using GNSS for RUC.

NORWAY

The National Public Road Administration (NPRA) has successfully introduced mandatory DSRC OBUs in HGV from 3.5 tons onwards. This was accomplished thanks to significant support from the government and user community, both who aim to give equal competitive conditions to transport companies in Norway.

Moreover, in March 2014, the NPRA selected an international information technology company to design, build and deliver a new, centralised road toll system, "AutoPASS Grindgut". This system is expected to process more than 470 million vehicle passages per year, accounting for approximately 1.8 bln € in road user charges.

The system is also expected to integrate roadside traffic data with modern new user accounts and NPRA's Customer Relationship Management (CRM) system. In addition, a message-oriented middleware, provided by the new system, will enable GNSS-based tolling, as well as other types of roadside services, if the NPRA decides to upgrade the current scheme.

POLAND

ViaTOLL has been analysing the possibility of extending the network of its current DSRC-based scheme to include lower class roads.

In support of this, in 2010 the National Automatic Toll Collection System (NATCS) Pilot Project of the Motor Transport Institute of Warsaw demonstrated the benefits of using an intelligent hybrid DSRC-GNSS OBU. The project confirmed that although such an OBU costs more than a DRSC-only tag, by investing more in OBUs, considerable savings in the construction of roadside equipment and operational costs can be realised. Moreover, GNSS technology permits complex tolling schemes and variable tariffs (based on road category, time of day, direction of travel, etc.), giving the road authority the ability to influence traffic behaviour, hence optimising road networks.

SLOVENIA

In mid-July 2015, the Motorway Company in the Republic of Slovenia (DARS) published a call for tender for the "establishment and operation of a multi-lane electronic toll system in free traffic on motorways and expressways". The deadline for submissions was 15 October 2015.

The call for tender did not specify the technology to be used. However, given that the corridor from-to the Koper port in Slovenia is one of the primal export corridors for Slovakia and Hungary, both of who have a GNSS-based RUC system, using GNSS could prove very beneficial towards Slovenia achieving interoperability with these MS.

SPAIN

The Spanish motorway network is the largest in Europe and third largest in the world by length, accounting for 16,583 km. However, only c. 20% of the network is subject to tolls using DSRC and/or toll booths.

After the economic crisis started in 2008, the delicate situation of the highway concessionaires has slightly stabilised, with traffic on toll roads increasing in 2014 for the first time in eight years. However, the industry still sees unequal competition from toll-free motorways. Moreover, both the country as a whole and the individual regions struggle to maintain the non-conceded motorways, which suffer from the wear and tear of HGV traffic.

Finally, HGV drivers frequently take advantage of alternative roads instead of using toll motorways. Among others, this situation has been the cause of numerous accidents in some regions of the country.

To remediate these issues, a GNSS-based HGV tolling on both highways and lower class roads would be highly beneficial. Specifically, Spain could benefit from Slovakia's model, where highways are tolled and traffic over parallel, lower class roads is also controlled by means of applying the same toll rates.

SWEDEN

In May 2015, the Swedish government assigned a committee to make proposals on how a distance-based RUC scheme for HGV can be designed. The objective of this committee is to require HGV traffic to pay for its societal costs (i.e. road wear and pollution). The tax will be applicable to Swedish and foreign trucks using Swedish roads. The study, through a report to be delivered in December 2016, is expected to propose a technical solution and the necessary procedural rules, along with suggestions for the design and scope of the tax and an impact assessment.

Sweden enjoys a sparse population, with relatively few vehicles using its extensive road network and small share of motorways and expressways. More so, secondary roads are often of good quality, offering almost the same average speed as motorways, especially for trucks. For these reasons, a country-wide control is necessary, for which GNSS looks to be the only viable solution.

Finally, for nearly 10 years, the ARENA project has been supporting the idea of introducing a RUC scheme. The project is supported and funded by the Swedish Transport Administration, Swedish Transport Agency, Swedish Governmental Agency for Innovation Systems and Region of Blekinge.

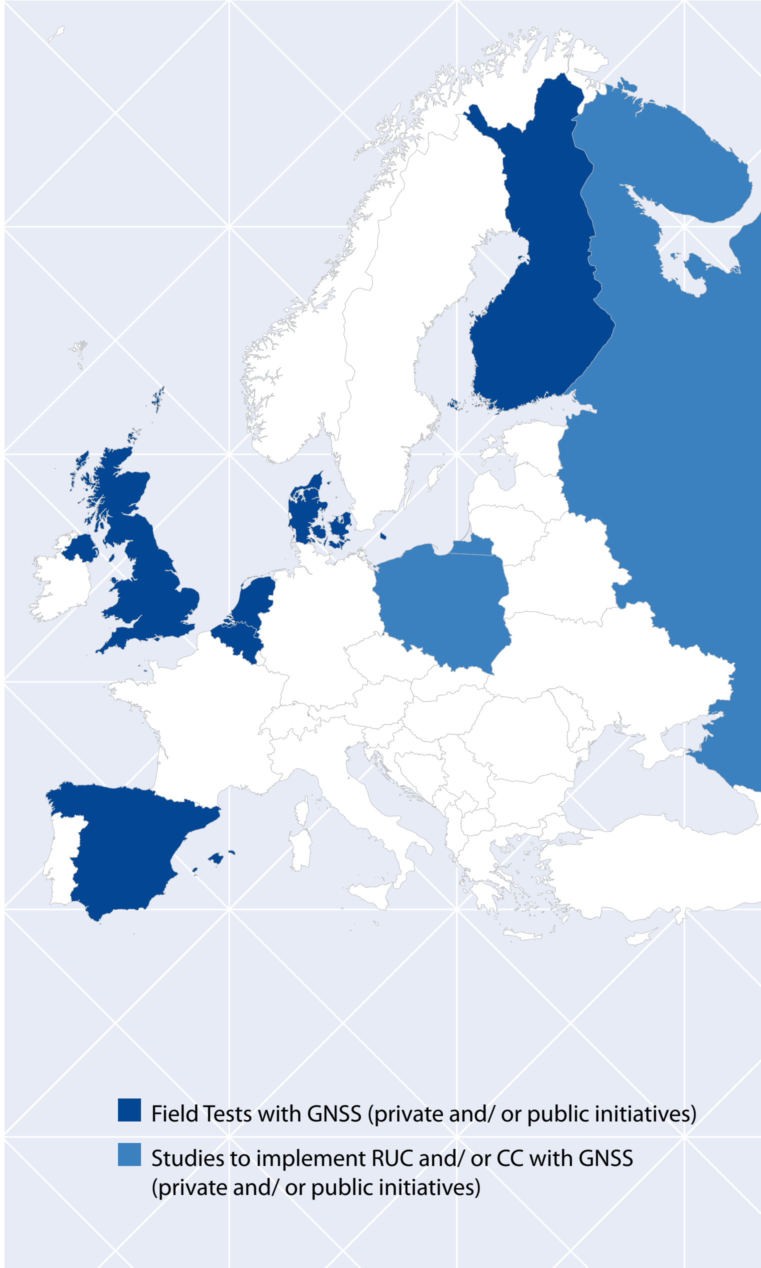
EMERGING APPLICATIONS

There have been several studies and field tests on the use of GNSS as a means of implementing RUC and/or Congestion Charging (CC) schemes for Passenger Cars and Light Vehicles (PC/LV) in Europe. More so, field tests aimed at obtaining knowledge and experience on the usage of GNSS technology and towards achieving interoperability and such other scenarios as toll rings (CC) or national-level RUC are in the works.

Although none of the countries that conducted studies or field tests in the past decided to implement a GNSS-based system for PC/LV, their reasoning was neither technical nor economical, but instead related to political resistance, legacy systems already in place or lack of public support.

Public support is key for successful CC or RUC initiatives. Without public buy-in, it is difficult to obtain the necessary political support to implement these initiatives. In general, acceptance has been poor due to two main reasons:

1. In the case of RUC, unwillingness to pay for the kilometres driven in a national road infrastructure
2. In the case of both RUC and CC, privacy concerns. As a result of the low awareness on how localisation technologies work, this was once a more prominent concern. However, thanks to the acceptance of other In-Vehicle Systems (IVS) based on position determination like eCall, the concern over privacy has largely been overcome.



BELGIUM

One thousand participants who live and work in the greater Brussels area have been selected for a trial of a km-based charging scheme. Each participant received an OBU in their car for a one month base period and two months of real testing. A survey of participants found that 63% rejected the system, with only 25% in favour. However, the trial reduced drivers' mileage by 5.5% overall and by 8% in cities. More so, rush hour congestion fell by a significant 3.6%.

Despite the negative feedback from participants, the application of the RUC system for PC/LV has not been discarded. However, it will not take effect in the short-term. Viapass has stated it believes in the future of variable RUC in Europe, recommending first to introduce it for HGV and then, possibly, for PC/LV.

DENMARK

As per Sund & Bælt, the future technology for charging motorists for using toll roads, bridges and tunnels will increasingly be based on satellite systems. As a result, the company wishes to obtain knowledge and experience in the use of GNSS technology and has decided to trial a new payment system that can replace or supplement the existing BroBizz, currently in use at its own facilities.

The trial in the greater Copenhagen area is ongoing, encompassing a number of vehicles driving pre-defined routes with GNSS OBUs from two different providers, allowing for a better understanding of the possibilities and challenges of using GNSS in urban environments and to research if the same road charge can be achieved for the same trip within the recommended EETS business model. The trial, to run for two to three years, will help identify problems with data capture and control through the use of GNSS and analyse the costs of charging via a GNSS-based system.

FINLAND

The report on "Fair and Intelligent Transport"[2] states that a kilometre-based tax (GNSS-based RUC scheme) would be a more flexible transport policy tool than the current tax system as it can be adjusted depending on time, place and type of vehicle, within the bounds of equal treatment of citizens. Moreover, a tax model based exclusively on vehicle use, coupled with fuel tax, would better serve the achievement of transport and environmental policy objectives than the existing tax regime.

Although the report states that a kilometre-based tax would require a more sophisticated and expensive system, the annual savings to society in the way of reduced accident and emission costs would be equal to the costs of collecting it.

Moreover, the Ministry-supported Traffic Lab initiative will make it possible to test intelligent transport applications in Finland, will help utilise the growth potential in Intelligent Transport Systems (ITS) and create a model that enables mobility service markets.

Traffic Lab has studied the effects of kilometre-based tax on mobility by looking into Finnish habits relating to mobility and into the effects a kilometre-based tax would have on them. The results have shown that 41% of the respondents would choose the kilometre-based tax, with 30% opting to stay in the current system. The respondents supporting kilometre-based taxation particularly liked how the new payment system would support the purchase of a new car and thus the abolition of the car tax.

2. Finland: Fair and Intelligent Transport. Working Group Final Report. The Ministry of Transport and Communications of Finland, February 2014

THE NETHERLANDS

After a period of no evaluation for a future RUC scheme, the Dutch Transport Ministry is working on a policy framework for road tolling. The requirements of the policy are stringent in the sense that toll collection will only be possible on new infrastructure when a toll free alternative is available. Only two road projects are expected to become subject to tolls in the mid-term: ViA15 and the Blankenburg tunnel.

However, the country is also seeking optimisation of its road network through GNSS-based ITS solutions. One of the schemes currently in trial is the "reward & influence" approach that aims to reduce traffic during rush hours. The reward model is not fed by subsidies, but through private partnerships with other businesses. It is key that this project demonstrate a viable business model for mobility pricing and create a valuable ecosystem for B2B partners.

POLAND

Traffic jams on highways cost Poland about 2% of its GDP every year. As a result, plans for making DSRC tags mandatory for PC/LV (already mandatory for HGV) are in the pipeline. Moreover, the General Directorate for National Roads and Motorways (GDDKiA) has studied the possibility of adding lower class roads to its RUC scheme, for which GNSS might be the only feasible solution.

The acceptance of RUC is high and the current system, although working well, is not well-suited for expansion to lower class roads.

RUSSIAN FEDERATION

The national RUC scheme for HGV, which started its operations in November 2015, is already the biggest GNSS-based RUC system worldwide. Moreover, ERA GLONASS, the Russian automatic emergency call system, which has been operational since the beginning of 2014, will be mandatory for all new cars starting 2017.

As per the GLONASS Union, who promotes the usage of navigation technologies in Russia, this technological platform will serve as a base for other public initiatives in ITS, including tolling systems.

SPAIN

During 2013, Cintra and Ferrovial developed the Satelise project, a platform that allows road tolls to be paid using an application for mobile terminals using GNSS-based positioning. Satelise gives users access to value-added interactive services, and their mobile tolling programme simplifies the process down to a tracking app similar to those used for Usage Based Insurance (UBI).

The smartphone app's role is simply to send position information to the server and to act as the customer interface. On the backend, the matching algorithms, toll detection and rating is conducted by the central system.

To date, over 10,000 transits have tested the software's reliability. The next step will be the implementation of pilot projects at concessions managed by Cintra.

UNITED KINGDOM

Plans to introduce a GNSS road tolling scheme for all vehicles were announced by the Transport Secretary in 2005, with prices based on road congestion. In 2007, an online petition against road pricing attracted over 1.8M signatures, equivalent to 6% of the UK driving population. More so, according to a 2007 public opinion poll, 74% of respondents were against road pricing. As a result of this lack of public support, plans for introducing a RUC scheme were terminated.

Since then, the political support of any RUC scheme in UK remains decisively low. However, there have been trials of GNSS systems for RUC. The CEDAR project was a technology and behavioural trial of distance-based RUC in the urban areas of Southern England. It used GNSS-based OBUs to improve transport logistics and reduce congestion, extending the successful trials previously carried out by Transport for London.

Field trials and user studies were undertaken by the Swindon Borough Council. Vehicles travelled their normal routes and volunteer drivers were analysed to determine behavioural change. The project concluded that GNSS technology was close to being acceptable for commercial use in real urban road pricing schemes.

A-GNSS	Assisted-GNSS
CDR	Charge Data Record
CRM	Customer Relationship Management
CS	Commercial Service
DSRC	Dedicated Short Range Communications
EC	European Commission
EDAS	EGNOS Data Access Service
EETS	European Electronic Tolling Service
EGNOS	European Geostationary Navigation Overlay Service
ERA GLONASS	Russian Automatic Emergency Response System
ETC	Electronic Toll Collection
EU	European Union
EU28	European Union Countries
GDDKiA	General Directorate for National Roads and Motorways (Poland)
GLONASS	Globalnaya navigatsionnaya sputnikovaya sistema (Russian GNSS)
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System (American GNSS)
HGV	Heavy Goods Vehicle
ITS	Intelligent Transport System
IVS	In-Vehicle System
LV	Light Vehicle
M2M	Machine-to-Machine
MEOSAR	Medium Earth Orbit Search and Rescue
MNO	Mobile Network Operator
MS	Member State
NATCS	National Automatic Toll Collection System (Poland)
NPRA	National Public Road Administration (Norway)
NTPS	National Toll Payment Services (Hungary)
OBU	On-Board Unit
OS	Open Service (Galileo/ EGNOS)
OTA	Over-the-Air
PC	Passenger Car
PRS	Public Regulated Service
RUC	Road User Charging
SBAS	Satellite-Based Augmentation System
SIM	Subscriber Identity Module
SME	Small and Medium Entreprise
SoL	Safety-of-Life
TSP	Toll Service Provider
UBI	Usage-Based Insurance
UMTS	Universal Mobile Telecommunications System
VH-KM	Vehicle-Kilometre (normalized distance measure)

The European GNSS Agency (GSA)

The GSA's mission is to support European Union objectives and achieve the highest return on European GNSS investment, in terms of benefits to users and economic growth and competitiveness, by:

- designing and enabling services that fully respond to user needs, while continuously improving the European GNSS services and Infrastructure;
- managing the provision of quality services that ensure user satisfaction in the most cost-efficient manner;
- engaging market stakeholders to develop innovative and effective applications, value-added services and user technology that promote the achievement of full European GNSS adoption;
- ensuring that European GNSS services and operations are thoroughly secure, safe and accessible.

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