



GNSS ADOPTION FOR ROAD USER CHARGING

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2022



More information on the European Union is available on the Internet (<http://europa.eu>).

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Cover Photo:

Redzinski bridge over the Oder river in Wroclaw, Poland.

A completely new and innovative GNSS-based RUC system replacing the former DSRC-based one has started operations in Poland in June 2021.

GNSS OVERVIEW	4
UNDERSTANDING THE BASICS OF GNSS	5
EUROPEAN GNSS PROGRAMMES	7
GNSS FOR DISTANCE-BASED CHARGING	9
HOW IS GNSS UTILISED FOR RUC?.....	10
MAIN BENEFITS.....	12
THE EUROPEAN ELECTRONIC TOLL SERVICE	13
REGULATION: PRESENT AND FUTURE	14
GNSS IN THE TOLL CHARGING ENVIRONMENT.....	15
MAIN STAKEHOLDERS OF EETS.....	16
BENEFITS WITH RESPECT TO EUROVIGNETTE	19
GNSS-BASED ROAD USER CHARGING	20
EXISTING AND PLANNED SCHEMES IN EUROPE.....	22
EXISTING AND PLANNED SCHEMES IN OTHER REGIONS.....	33
POTENTIAL SCHEMES WORLDWIDE	38
GNSS-BASED CONGESTION CHARGING	44
EXISTING AND PLANNED SCHEMES WORLDWIDE	45
POTENTIAL SCHEMES WORLDWIDE	46
EMERGING TRENDS	48
CONVERGENCE OF RUC AND FLEET TELEMATICS	49
SMART TACHOGRAPH USE FOR RUC.....	50
BYOD – BRING YOUR OWN DEVICE: SMARTPHONES USE FOR RUC.....	50
ANNEX	52
ACRONYMS	52

GNSS OVERVIEW



UNDERSTANDING THE BASICS OF GNSS

WHAT IS GNSS?

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

- **Global constellations:** GPS (USA), GLONASS (Russian Federation), Galileo (EU), BeiDou (PRC).
- **Regional constellations:** QZSS (Japan), IRNSS (India), BeiDou regional component (PRC).
- **SBAS:** WAAS (Wide Area Augmentation System, USA), EGNOS (European Geostationary Navigation Overlay Service, EU), MSAS (MTSAT Satellite Augmentation System, Japan), GAGAN (GPS-aided GEO augmented navigation, India), SDCM (System for Differential Corrections and Monitoring, Russian Federation), BDSBAS (BeiDou Satellite-Based Augmentation System, PRC)

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. These signals allow the receivers to calculate the current local time with high precision and thus achieve time synchronisation. There are four global constellations.

Galileo (www.gsc-europa.eu)

Following the declaration of initial services on 15 December 2016, Galileo has steadily continued its ongoing deployment. The programme started launching its so-called 'Batch 3' satellites in 2021 to complete and replenish its nominal Galileo 1st generation constellation. At the same time, evolution studies are ongoing in preparation for the first batch of the second generation of Galileo satellites.

GPS (www.gps.gov)

The USA is currently engaged in an ambitious GPS modernisation programme, which has been deploying new satellites (GPS III) since the beginning of 2018. Five satellites featuring the new L1C signal, which is almost identical to its Galileo OS counterpart on E1, have already been launched. The GPS III satellites also broadcast the legacy L1 and the more recent L2C and L5 signals, opening the door to the availability of four civil GPS signals sometime in the future.

GLONASS (www.glonass-iac.ru/en)

GLONASS-K is the latest generation of GLONASS satellites. The first of these entered into service in February 2016. The previous generation GLONASS-M satellites, which were used until 2019 for constellation maintenance, have been replaced by GLONASS K1 and K2 as of 2020. These satellites also feature improved clock stability, along with new control, command and ODS technologies. In the longer term (post 2025), the current MEO-only constellation could be complemented by six additional satellites in Highly Elliptical Orbits (HEO).

BeiDou (en.chinabeidou.gov.cn)

The third generation of the BeiDou system (BDS-3) reached full deployment in June 2020, with 30 satellites (24 MEO, 3 GEO and 3 IGSO) in the nominal constellation, providing global and regional services. The system transmits signals on the B1 (E1/L1), B2 (E5/L5) and B3 (~E6) frequencies. Sharing frequency bands and closely resembling signal waveforms with GPS and Galileo, BDS-3 significantly contributes to the interoperable, multiple GNSS world. With 30 satellites plus possible in-orbit spares, BeiDou operates the world's largest constellation.

SATELLITE-BASED AUGMENTATION SYSTEMS

SBAS is a method for improving a navigation system's attributes, such as accuracy, reliability and availability. It does this by integrating external information that is sent from geostationary or geosynchronous satellites into the calculation process.

There are four operational SBAS with plans for continued improvements: WAAS (USA), EGNOS (EU), MSAS (Japan) and GAGAN/NavIC (India). There are also five SBAS in various phases of development: SDCM (RU), BDSBAS (PRC), A-SBAS (ASECNA), KASS (South Korea) and SPAN (Australia and New Zealand).

The global installed base of in-use GNSS devices is forecasted to increase to 10.6 billion in 2031, with Asia-Pacific dominating the market in terms of revenue coming from devices and services (36% and 40% of the global share respectively in 2021). In terms of global annual GNSS receiver shipments, the market is forecasted to increase from 1.8 billion units in 2021 to 2.5 billion units by 2031. The vast majority of these shipments will be related to the consumer solutions, tourism and health segments. Thanks to the enormous quantities of smartphones and wearables being sold on an annual basis, these shipments will make up roughly 92% of all global annual shipments. From a regional point of view, it is clear that Asia-Pacific will continue its reign as the largest market.

In this context, out of the 1.8 billion GNSS units shipped in 2021, more than 60% were Galileo enabled – a remarkable and promising result for the European GNSS programme.

As to RUC in Europe, the GNSS schemes already active entail around 5 million registered vehicles (sum of all registrations from each country) and could reach around 7 million when the Danish, Lithuanian and Dutch systems come online. This does not specifically mean that there are 5 million (or that there will be 7 million) Onboard Units (OBU) in use. Instead, because the European Electronic Toll Service (EETS) has recently begun to flourish, and the concept of a single OBU capable of being used in several countries is becoming a reality, the total number of RUC GNSS devices deployed will actually decrease (see chapter 'THE EUROPEAN ELECTRONIC TOLL SERVICE').

EUROPEAN GNSS PROGRAMMES

EGNOS

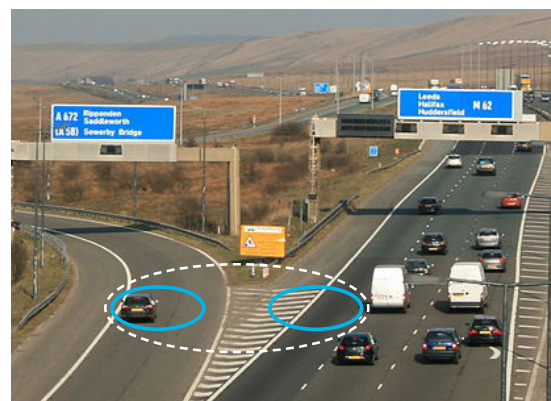
The European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system that increases the accuracy of GPS positioning (and soon Galileo positioning) by reducing the influence of ionosphere and system errors. It also provides the user with information on GPS' reliability in Europe.

EGNOS provides three services:

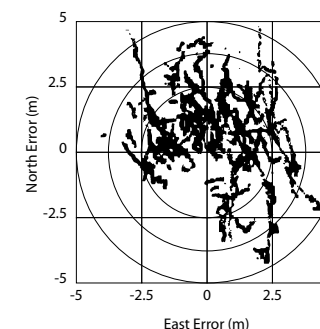
- 1. Open Service (OS):** Available free to the public for mass-market receivers and such common user applications as road tolling.
- 2. Safety of Life (SoL):** For safety-critical transport applications, namely in civil aviation, this service provides enhanced and guaranteed performance and features 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.

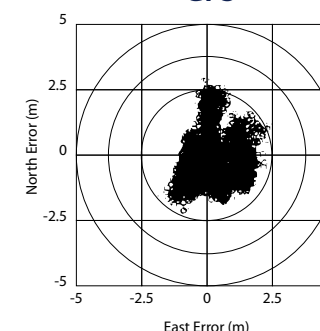
EGNOS is suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels, as well as applications where an accuracy of 1-2 metres is sufficient (e.g. electronic tolling, tracking of dangerous goods).



Source: ©RobChafer



GPS



GPS + EGNOS

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.

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

Galileo is the European GNSS, providing standalone navigation, positioning and timing information to users worldwide. Unlike other systems, Galileo is under civilian control and has been designed to meet the diverse needs of different user communities. The four Galileo services (Open Service, High Accuracy Service, Search and Rescue and Public Regulated Service) offer various levels of accuracy, robustness, authentication and security.

Galileo allows positioning to be determined more accurately, even in cities where high-rise buildings obscure signals from satellites. Galileo also offers several signal enhancements, making the signal easier to track and acquire and more resistant to interference and reflections.

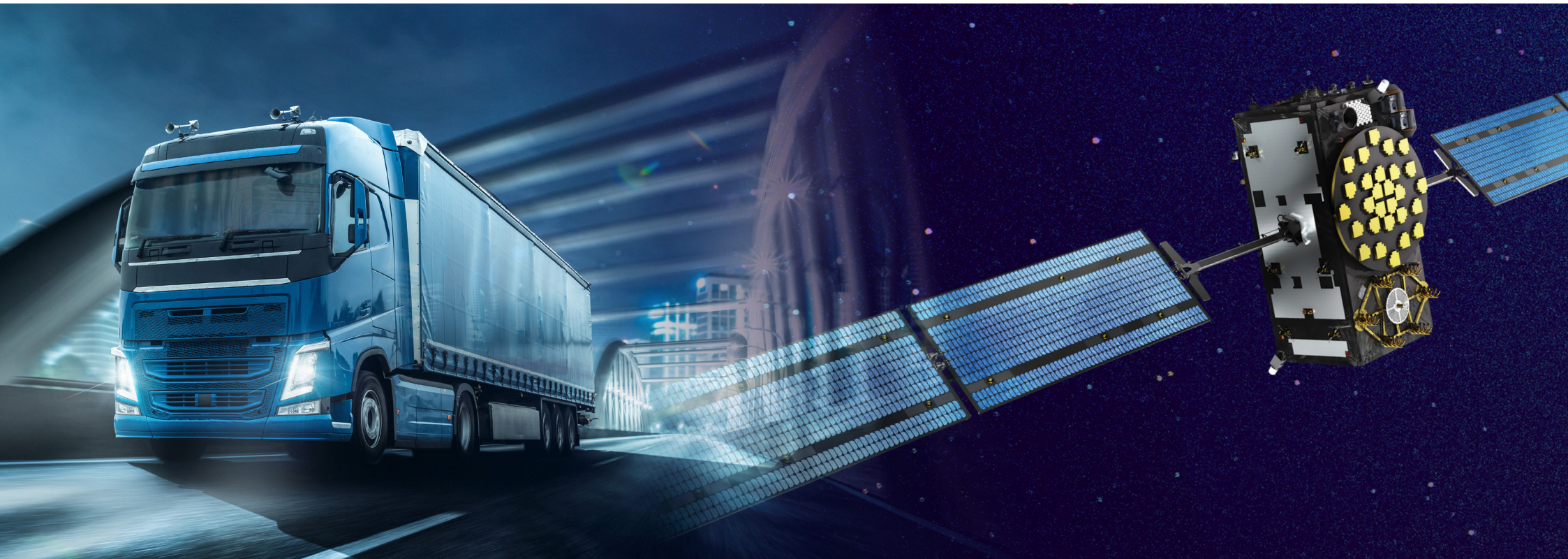
Galileo has been providing live services to GNSS users across the globe since 2016. Once fully operational, the Galileo programme will offer four high-performance services worldwide:

- 1. Open Service (OS):** Galileo's open and free of charge service offers both positioning and timing. In the future, the Galileo OS will also provide Navigation Message Authentication, which will allow it to detect GNSS signal spoofing attacks.
- 2. High Accuracy Service (HAS):** A service complementing the OS by providing an additional navigation signal and added-value services in a different frequency band (E6) and via the internet. The target performance is 20 cm horizontal accuracy.
- 3. Public Regulated Service (PRS):** This service is restricted to government-authorized users using sensitive applications that require a high level of service continuity.
- 4. Commercial Authentication Service (CAS):** A service providing users with the capability to obtain an authenticated Galileo PVT solution.
- 5. Search and Rescue Service (SAR):** Europe's contribution to COSPAS-SARSAT, an international satellite-based search and rescue distress alert detection system.

An additional feature of the Open Service, provided on E1 and E5 signals, is the Navigation Message Authentication (OSNMA). Currently in testing, the OSNMA is expected to allow users to verify that a navigation message comes from a Galileo satellite and not a potentially malicious source. This feature will greatly contribute to the mitigation of spoofing attacks, offering a clear differentiator relative to any other GNSS available to the civil community for mass market applications. The road segment in particular will benefit from the OSNMA service, especially as to such liability-critical applications as the smart tachograph (where GNSS and OSNMA are mandatory) and GNSS-based RUC schemes.

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GNSS FOR DISTANCE-BASED CHARGING



GNSS FOR DISTANCE-BASED CHARGING

HOW IS GNSS UTILISED FOR RUC?

Depending on the specifics of the RUC scheme, GNSS can be used in three different ways. The most sophisticated way involves the user being charged based on the actual route driven. GNSS can also be used to support or complement other technologies, such as Automatic Number-Plate Recognition (ANPR), in which the location data from GNSS helps identify the presence of the vehicle in the vicinity of a toll barrier (i.e. within a toll booth). Lastly, GNSS can be used to record distance irrespective of the specific route driven.

LOCATION BASED CHARGING

This scheme is used when some usages are subject to charges while others are not. The charging depends on the reported position and distance.

To properly determine the amount to charge a user, a series of steps must be followed. These correspond to the workflow of an 'intelligent client' approach, which can vary slightly depending on the solution vendor.

- 1. Positioning:** The OBU integrated GNSS receiver periodically provides information such as position, speed, orientation and degree of confidence (e.g. on a second-by-second basis).
- 2. Matching 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 is downloaded to the OBU through an Over-the-Air (OTA) software update. Maps can be updated when needed 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 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 generates a Charge Data Record (CDR). In this case, the position of the vehicle is not transmitted. However, for potential legal reasons, it is stored in the OBU for a specified period of time.

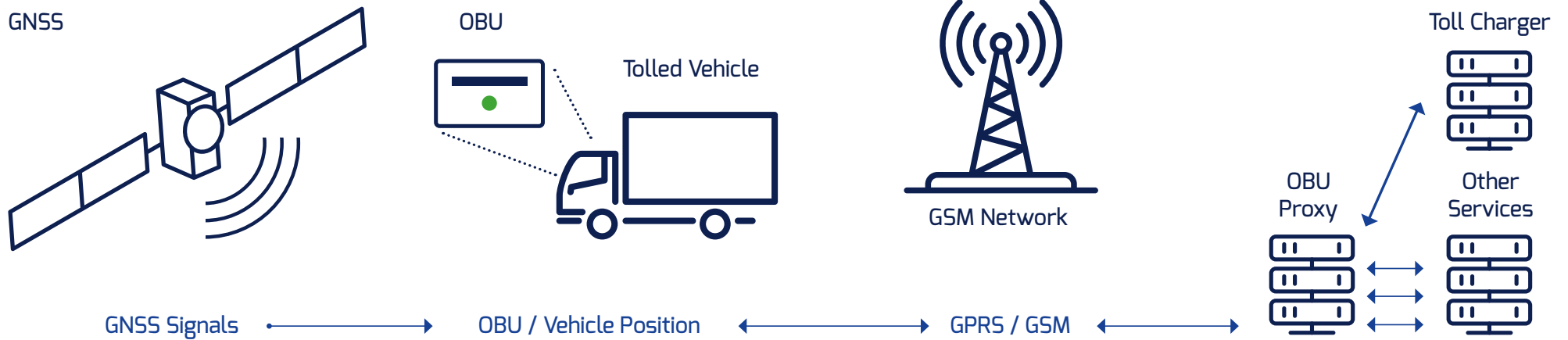
- 5. Transmission:** The stored CDRs are periodically reported by the vehicle's OBU to the Toll Service Provider (TSP) via a secure transmission using a Mobile Network Operator (MNO) (e.g. GPRS, UMTS, etc.). The set of CDRs received from a particular vehicle is then processed for billing on the back-end or central system of the Toll Charger.

This process may vary depending on the TSP and the configuration of the OBU. For example, when a '**thin client**' approach is used, the matching, toll detection and rating are conducted by the central system. The OBU is limited to securely transmitting the coordinates (i.e. the vehicle's position) to the central system on a periodic basis by means of the GNSS proxy and 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.

In Europe, the 'thin client' approach is key for the interoperability of EETS providers in different toll domains. For instance, when the biggest toll domain in the EU (i.e. Germany) moved from an 'intelligent client' to a 'thin client' approach in 2018, this triggered the interest and subsequent accreditation of different EETS providers which now offer toll payment services in that country.

Another important aspect of a 'thin client' approach is that current legislation (i.e. Directive (EU) 2019/520) allows EETS providers to facilitate services other than tolling, so long as the operation of such services does not interfere with the toll services of any EETS domain.

Finally, the 'thin client' approach, which enables the matching of algorithms onwards at the toll charger (TC) premises, allows them to have a higher control of the toll network and higher economic benefits as they have most of the process done in-house and not outsourced to the EETS provider or intermediaries.



GEO-LOCATION AS A COMPLEMENT TO OTHER TECHNOLOGIES

Smartphones can be used in some toll collection systems as an add-on component, such as for identifying license plate numbers using ANPR.

In some cases, smartphones with GNSS complement ANPR as a way to open the barrier at toll booths (e.g. Satelise in Catalonia, Spain). In theory, they can also be used in a multi-lane, free-flow scheme with no barriers, as has been proposed in Indonesia.

In addition to added comfort for occasional users, there are numerous advantages for operators who integrate smartphones into the toll collection process. For example, doing so can help increase overall tolling performance while also decreasing operating costs. Investing in these mobile tolling services pays off quickly given that they significantly reduce the efforts needed for manual image validation and reduce the loss of toll revenue arising from manually unreadable license plate numbers. The smartphone app is also able to integrate additional services, ranging from traffic congestion warnings and the payment of toll fees to individualised services for toll road users.

Every time a vehicle passes through a toll collection point, two processes are initiated. First, a video camera at the tolling station records an image of the license plate and sends it to the back office system. Second, the smartphone app detects that the driver has entered a geo zone and likewise transmits the passage to the back office system. Here, the two pieces of information are merged based on location and time. This avoids the need to manually validate license plates, thus saving both time and money.

DISTANCE RECORDING

Electronic distance recording is the simplest use of GNSS for RUC. It is used in some schemes worldwide (e.g. Switzerland, New Zealand and some states in the USA) in which all roads are subject to charge.

With electronic distance recording, GNSS is either used to validate a primary distance measurement by means of the on-board odometer or as the primary source of distance tracking/ counting. The location of the vehicle is not taken into account for charging, but only to determine whether the vehicle is within a certain region (e.g. in Switzerland and in some states in the USA).

A common aspect of such schemes is that users have the possibility of reporting kilometres driven by other means, such as paper-based annotations of the mechanical odometer or photos of the dashboard odometer. However, most users choose GNSS-based reporting by means of an OBU due to its simplicity, convenience and complementary value-added services.

GNSS FOR DISTANCE-BASED CHARGING

MAIN BENEFITS

There are many benefits to using GNSS for RUC, 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 both 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 means nearly 80% less roadside infrastructure (compared, for example, to microwave technologies), thus minimising 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. Data traffic costs, once one of the main disadvantages to its implementation, are now negligible. The European Union's mobile communications roaming directive has further eased the barriers to operate abroad.



Source (from upper left to bottom right): eroadglobal.com, www.ttm.nl, Bosch, viapass.be, ctfassets.net, dkv-mobility.com, tollpass.bg, as24.com, platon.ru, mststolls.com, untrr.ro

FLEXIBILITY

Rapid changes can be implemented

REVENUE POTENTIAL

SP can include several VAS to their offer

TRAFFIC MANAGEMENT

Dynamically influence traffic behavior

EXTENSIBILITY

Example of a network extension in 3 months

ENVIRONMENT (AND COST)

Around 80% less roadside infrastructure

LOW TRANSACTION COSTS

Data traffic costs are now almost negligible

THE EUROPEAN ELECTRONIC TOLL SERVICE



THE EUROPEAN ELECTRONIC TOLL SERVICE

Directive 2004/52/EC and the related Decision 2009/750/EC set out to achieve the interoperability of all EU electronic road toll systems. To do this, they aimed to avoid the proliferation of incompatible systems, which in turn could compromise both the smooth operation of the internal market and the achievement of transport policy objectives.

The directive stipulated that a European Electronic Toll Service (EETS) be created. The EETS sought to cover all EU road networks and tolling infrastructures on which road usage is declared electronically by means of a single OBU. It also defined the permitted technological solutions, namely Direct Short Range Communications (DSRC) and satellite positioning (GNSS) coupled with mobile communications.

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

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

The key objective behind the EETS is to allow road users to pay tolls throughout the EU with one subscription contract, one service provider and one OBU. To be the most effective, EETS should be a part of all electronic tolling infrastructure. By limiting cash transactions at toll stations and eliminating cumbersome procedures, EETS will help improve traffic flow and reduce congestion.

The EETS defines three main stakeholders: users, EETS providers and toll chargers (TC). The EETS provider concludes contracts with users and grants 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 decided by the Member States in compliance with EU legislation.

REGULATION: PRESENT AND FUTURE

The new Directive (EU) 2019/520 on EETS entered into force on 18 April 2019, while the Implementing Regulation (EU) 2020/204 has been in effect since 19 October 2021. This new 'EETS Directive' repeals Directive 2004/52/EC and amends and clarifies provisions related to the following key aspects (further described in subsequent boxes):

- The rights and obligations of EETS Providers, inter alia by easing the rules regarding access to EETS domains to provide electronic toll services and by specifying the rules regarding the remuneration to which EETS Providers are entitled;
- The obligations of toll chargers, in particular by providing more transparency between EETS providers and EETS users; and
- A system for exchanging information between Member States, allowing for the identification of the person and the vehicle subject to the charge in case of failure to pay the toll.

Access to toll domains and remuneration of EETS providers: Currently, EETS providers must service all TD in the entire EU – a requirement that has proven to be unrealistic, very costly and without a clear benefit for most EETS users in the short- to mid-term. The new EETS Directive allows for more limited domain coverage. Furthermore, it explicitly specifies the right of an EETS provider to be remunerated by the TC with a transparent, non-discriminatory methodology, which must be equal for all EETS providers accredited for a given TD. It may also differ from that of the National Service Provider (NSP), but only in clearly justified cases to avoid non-equal treatment.

Obligations regarding the transparency of TC: Besides transparency with respect to the remuneration of EETS Providers, all rebates or discounts on tolls offered by a Member State or a TC to road network users must be transparent and publicly announced. They must also be available on the same terms to clients of EETS providers.

Procedure for exchanging data between Member States: Each Member State must designate a national contact point with the power to conduct automated searches on data relating to vehicles and holders of vehicles for identification purposes. The exchange of data between MS may only take place between national contact points and must be carried out using the European Vehicle and Driving Licence Information System (EUCARIS). The MS in whose territory there was a failure to pay a road fee is only permitted to use the data obtained to establish who is liable for the failure to pay that fee

In the new 'EETS Directive', the provisions regarding GNSS and DSRC remain unchanged while ANPR is added as a technology. Moreover, EETS providers are permitted to provide users of LCV/PC with DSRC OBU only, without prejudice, until 31 December 2027. However, as to the right of MS introducing electronic road toll systems for LCV/ PC based on GNSS, this provision clearly favours the adoption of GNSS technology as its benefits have already been understood.

GNSS IN THE TOLL CHARGING ENVIRONMENT

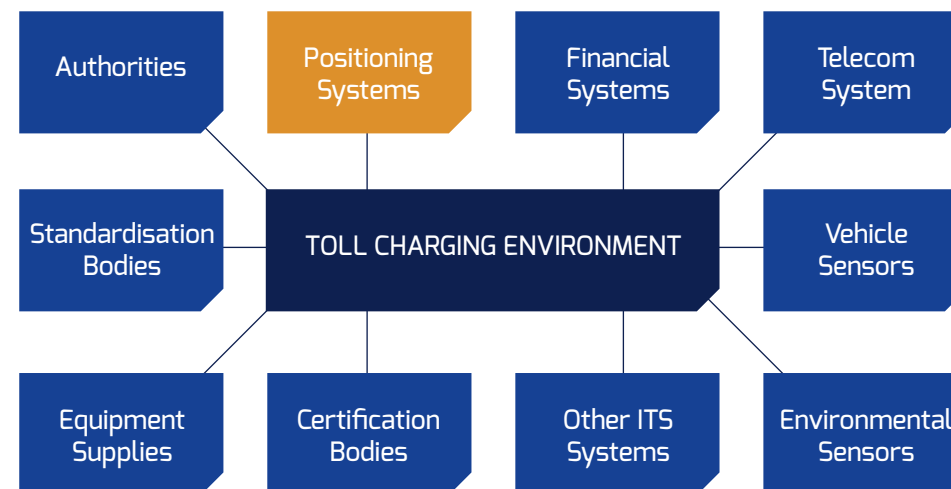
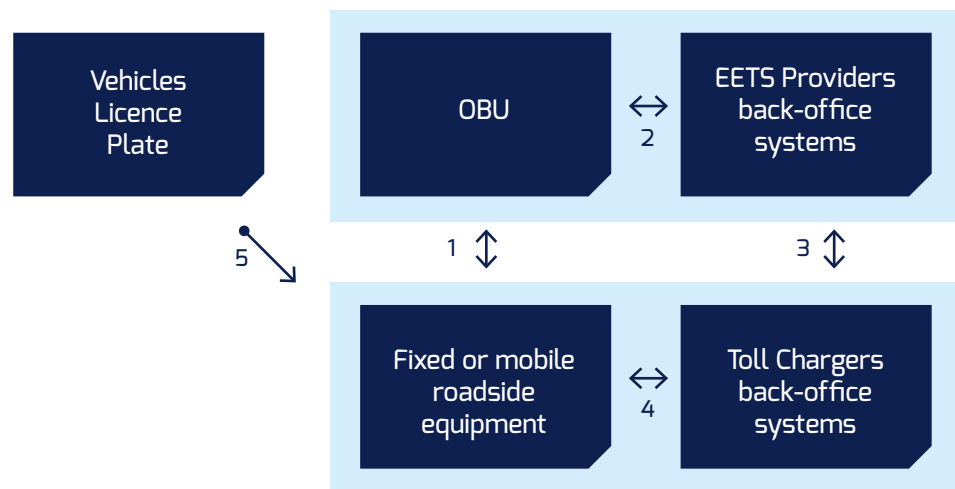
Based on Annex I (EETS Interfaces) of Implementing Regulation (EU) 2020/204, the technical systems and interfaces essential to the EETS interoperability scheme are the ones expressed in the figure below. All other systems and interfaces are implemented under the responsibility of the relevant stakeholder (i.e. TC or EETS provider). This allows for a differentiation of the services on the market and supports fair market competition.

The EETS general architecture does not require a specific method to be used for detecting toll events, especially for GNSS-based schemes. Instead, EETS providers may implement two different solutions: "smart clients", which allow for toll calculation inside the OBU, or "thin clients", which only gather time/position data and reports it to the EETS providers' back-office systems for further processing. It should be noted that the latter actually allows EETS to flourish. For example, when the German TC changed its system from using smart to thin clients, the provision of EETS services by third parties other than the NSP were made possible.

The proposed EETS general architecture defines the main interfaces between the entities.

1. DSRC charging transactions (ETSI ES 200674-1 V2.4.1 in Italy and EN 15509:2014 in the rest of Europe), real-time compliance checking transactions (EN ISO 12813:2015) and localisation augmentation for GNSS-based tolling systems (EN ISO 13141:2015).
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. In general, DSRC and GNSS systems shall comply with CEN/TS 16986:2016/AC:2017. Furthermore, there are differentiated interfaces with respect to the technology:
 - a. **For all three technologies:** Exchange of information to support exception handling from toll chargers to EETS providers, of EETS user-related lists, of trust objects, of toll context data and of payment claims according to the adopted business model (optional)
 - b. **For GNSS-based TD:** submission and validation of GNSS toll declarations, exchange of payment announcements according to the adopted business model (optional) and of billing details according to the adopted business model (optional)
 - c. **For DSRC-based EETS TD:** Exchange of billing details and of payment claims based on DSRC charging transactions (optional)
 - d. **For ANPR-based tolling:** exchange of billing details (optional) and of payment claims based on ANPR charging transactions (optional)
4. Charging or enforcement data from RSE to back-office systems. No application standards are currently foreseen for this interface.
5. Electro-optical imaging systems at the TC's fixed or mobile equipment at the roadside, providing means for ANPR, in toll systems where the installation and use of an OBU is not mandatory. Information is not 'transmitted', but is instead read by the ANPR device.

THE EUROPEAN ELECTRONIC TOLL SERVICE



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 TD). 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 can be 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 four kilometres.

MAIN STAKEHOLDERS OF EETS

EETS USERS (ROAD USERS)

EETS users may subscribe to EETS through any EETS provider, regardless of nationality, state of residence or state in which the vehicle is registered. When entering into a contract, EETS users shall be duly informed about the processing of their personal data and the rights stemming from applicable legislation on the protection of personal data. EETS users may seek subscription with the EETS provider of their choice within any Member State. The EETS provider must pay particular attention to inform the user about the treatment of the users' personal data, according to applicable legislation.

An EETS user is responsible for paying tolls to the respective EETS provider, which shall be deemed to fulfil the EETS user's payment obligations towards the relevant TC. The payment of the toll by the user to the respective EETS provider voids any further responsibility for toll payment by the user towards the TC.

TOLL CHARGERS

TCs have no direct contact with EETS users, except for enforcement, and only when necessary. In this sense, they do not have to perform detailed user management and can thus concentrate on road and traffic management.

TCs must publish an 'EETS domain statement' outlining the general conditions for EETS providers to access their TD. 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 TC with whom they conclude a contract.

In addition, TCs must publish the list of all EETS providers operating on their domains and are responsible for the application of the tolling policies.

A key institution in this group of EETS stakeholders is ASECAP (European Association of Operators of Toll Road Infrastructures), which brings together most EETS TCs along with members of other non-EU countries. ASECAP's purpose is to defend and develop the system of motorways and road infrastructures in Europe, applying tolls as a means of ensuring the financing of their construction, maintenance and operation.

ASECAP and several of its members played an important role during the REETS project (Regional EETS), which had the objective of supporting EU legislation regarding the interoperability of electronic road toll collection. REETS also aimed to deploy EETS compliant services in cross-border regional areas by reducing business uncertainty for EETS providers, creating a basis to ease the bilateral negotiations between TCs and EETS providers and developing a common understanding of the service components provided by the different stakeholders.

EETS PROVIDERS

EETS providers are private businesses that act as intermediaries between TC and EETS users across multiple MS and are registered in the MS where they have established the services.

Their fundamental role is to relieve multiple TC from the burden of managing multiple EETS users. They manage the hardware and software necessary for tolling transactions, providing EETS users with a single contract valid across multiple MS.

EETS providers must follow a standardised process to adapt to EETS regulations, with obligations for registration and certification that need to be met in order to provide services across multiple TD. The main obligation is to ensure the availability of an interoperable OBU (DSRC and/or GNSS).

The registration and certification process has been historically complex, time-consuming and costly for EETS providers. However, once accomplished, the provider can start operations, being constantly monitored with quality audits and measurements as any significant changes in the certified system would require that the certification process be restarted.

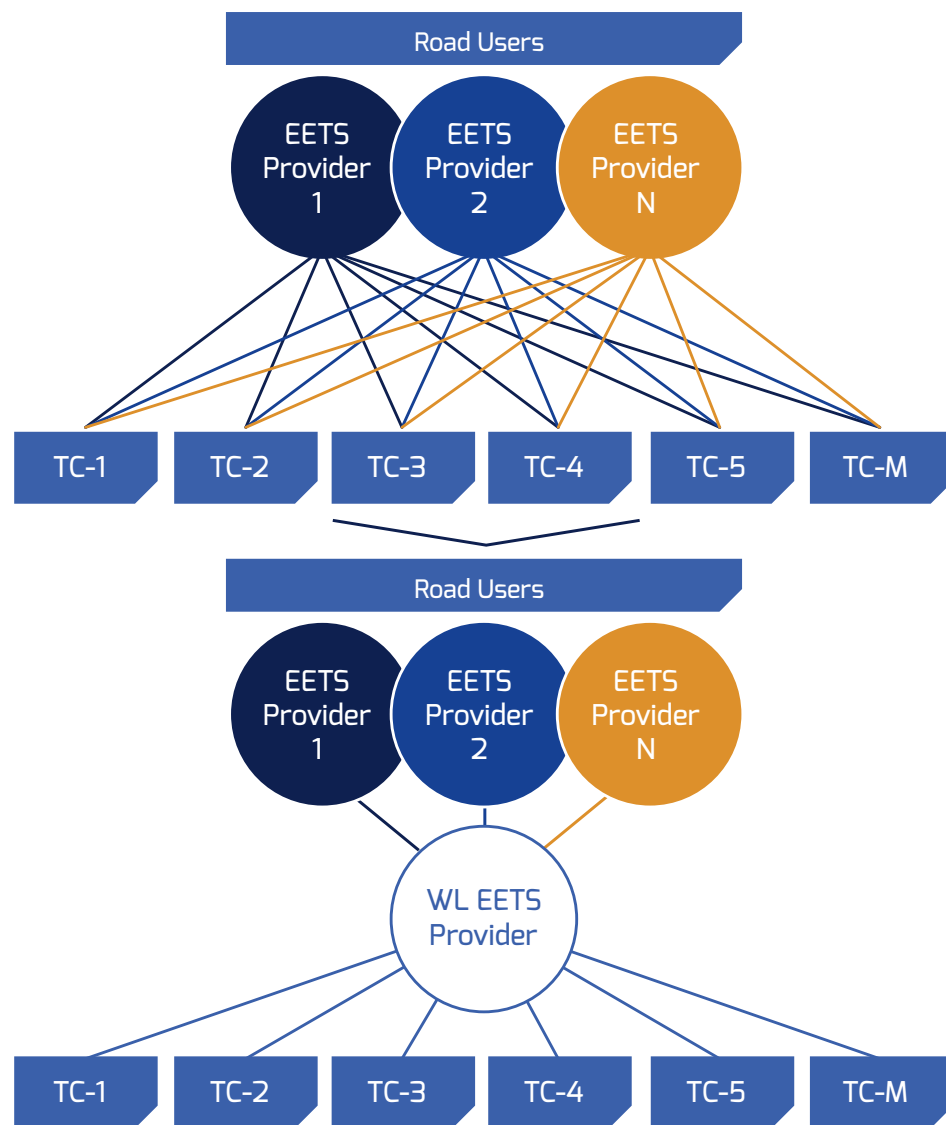
The key aspect improved by the new 'EETS Directive' is the **assured remuneration for EETS providers by the TC** to support tolling services within their TD. Prior to this improvement in the EC Regulations, the business case was, in general, unviable for EETS providers, even if, in some cases, value added services were part of the offer of some independent (i.e. no NSP) EETS providers.

For the benefit of EETS users and the health of the tolling market, in recent years, several EETS providers entered the market with different business models and approaches, from developing their own OBU (e.g. EuroWAG and Telepass) to white-labelling their solutions (e.g. Telepass). This allows historically non-EETS providers (e.g. fuel card issuers) in close contact with road users to be able to provide tolling services without having to make considerable investments in system development and the management of contracts with several TCs. These elements have created a healthy environment of competition, which ultimately provides a collective advantage for road users.

In fact, the EETS providers market is changing fast, with new entrants and consolidations taking place, which allow for new business models not previously possible. As the EETS market becomes more competitive, scale and market share will be key drivers of profitability and the continued ability to invest in new TD and services.

One of the main evolutions is the emergence of the white label model, where EETS providers have no direct contract with the EETS users. Instead, they provide white-labelled services to a re-seller, which can be a fleet service provider (e.g. fuel card issuer), a telematics service provider or an Original Equipment Manufacturer (OEM, i.e. truck manufacturer). In this model, the white label EETS provider must still guarantee toll payment to the TC, but they receive their own payment guarantee from the customer (i.e. the re-seller). By partnering with other fleet service providers, EETS providers are potentially able to expand the use of their OBU and platform and enter new markets faster. Although this may decrease revenues, it also decreases, or at least shares, costs and risks. In this sense, a likely situation is that they will generate strong growth in the market for EETS services but shrink the market for EETS providers.

THE EUROPEAN ELECTRONIC TOLL SERVICE



TC – Toll Charger
 EETS Provider – European Electronic Toll Service Provider
 WL EETS Provider – White Label European Electronic Toll Service Provider

As to ASECAP for TC, the institution that brings together most EETS providers is AETIS (Association of Electronic Toll and Interoperable Services), which represents its members as a stakeholder group within the EU legal framework for EETS. AETIS has also been a key player in the REETS project, which ultimately created the basis for the EETS provision market to flourish.

The following are the current members of AETIS and/or registered EETS providers in Europe. **15 out of 20 (75%) already provide a GNSS OBU among their offers (own or white-label).**

AETIS Member
 Registered EETS Provider
 GNSS OBU offered

BENEFITS WITH RESPECT TO EUROVIGNETTE

European countries differ in their geography, population density and road networks. In terms of the charging systems, time-based charging using vignettes was traditionally considered to be a cost-effective alternative to distance-based charging (EETS).

The EU is currently revising its road charging rules (Eurovignette Directive) to address greenhouse gas emissions and other environmental impacts, congestion and road infrastructure financing. The main change over the current system will be the introduction of a new, EU-wide tool for varying infrastructure and user charges with regard to heavy-duty vehicles based on CO2 emissions, with preferential treatment to zero-emission vehicles.

The scope of the rules will be extended from heavy goods vehicles only to other vehicles for which EU Member States may wish to apply charges, such as buses, vans or passenger cars. However, the purpose would be to **gradually replace time-based user charges with distance-based charges, which are considered fairer, more efficient and more effective.**

As a matter of fact, the low social acceptance of vignettes is influenced by their questionable ability to reduce congestion, as demonstrated in the current vignette schemes, and the fraud risks linked to a simple technology. On the contrary, EETS based on GNSS allows one to discriminate on the basis of a vehicle's CO2 emissions, secure higher revenues in the long term and explore new business cases in enhanced mobility services for citizens.

GNSS-BASED ROAD USER CHARGING



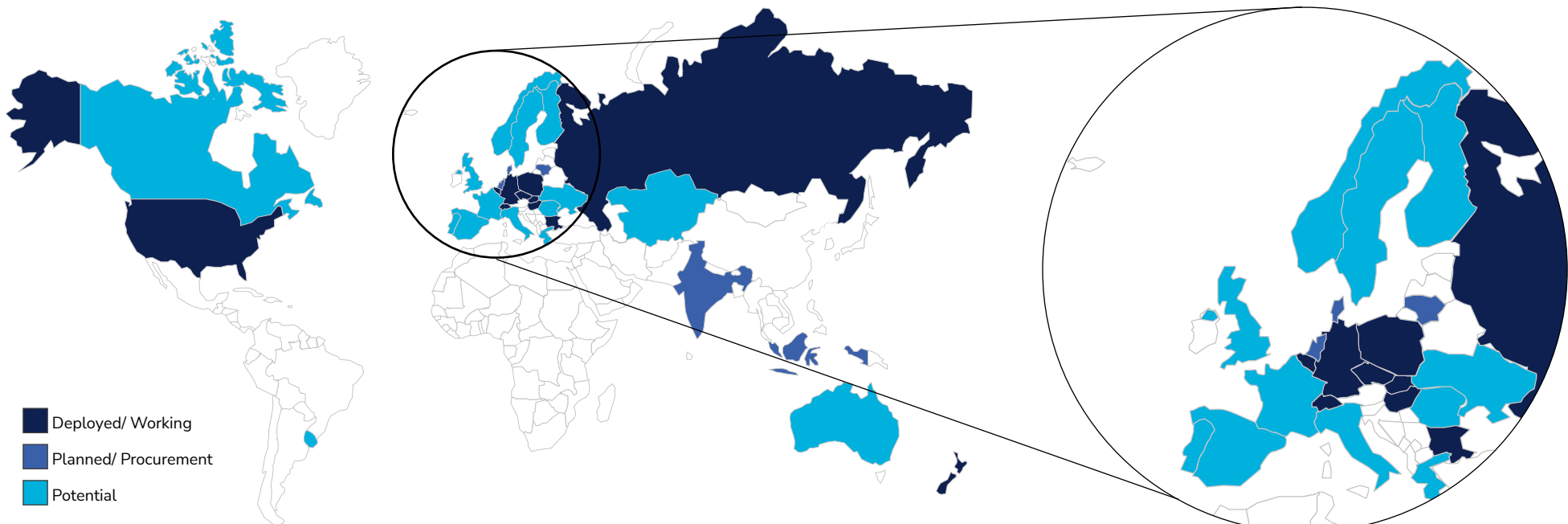
Because the advantages of using GNSS for RUC of HGV are already demonstrated and understood in Europe and abroad, more and more RUC schemes are beginning to use this technology.

In Europe, there are currently seven European Member States (MS) (Belgium, Bulgaria, Czech Republic, Germany, Hungary, Poland and Slovakia), plus non-MS Switzerland, that are using GNSS for their RUC schemes for HGV. Four other Member States (Denmark, France - regional -, Lithuania and the Netherlands) either have plans to launch a GNSS RUC scheme or have already started the procurement process for such a system. These three countries aim to launch their systems within the next three years.







Outside Europe three countries (New Zealand, the Russian Federation and the United States of America) are already implementing, at least at a regional level, a distance-based RUC scheme that utilises GNSS. India and Indonesia also intend to pursue a GNSS RUC scheme and have already started the procurement process, with plans to launch the system within the next two years.

Apart from these deployed and planned systems, there are 14 countries known to have recently analysed the use of GNSS for RUC. Each is at a different level of advancement in terms of selecting the technology and/or the political and legal background required for implementation. Nine out of these 14 countries are European Member States (Finland, France, Greece, Italy, Norway, Portugal, Romania, Spain and Sweden).

In the following sections, 11 countries with operational or planned RUC schemes using GNSS are presented, with an overview of their key figures and most recent updates (Existing and Planned Schemes in Europe). Next, five countries outside Europe with operational or planned RUC schemes using GNSS are presented with an overview of their key figures and most recent updates (Existing and Planned Schemes in Other Regions). Finally, the remaining 14 countries that can potentially implement a GNSS-based system for RUC are presented with some recent updates (Potential Schemes Worldwide).



BELGIUM

 Start of activities 1 April 2016	 Registered Vehicles c. 750,000
 Target Vehicles HGV with 3.5+ tonnes	 Annual Tolling Income €814 mln (2021)
 Total Kilometres c. 6,800 km of roads	 EETS Providers Axxés, Eurotoll, Telepass, Toll4Europe and Total (Approved) MSTS, TollTickets and EuroWAG (In process)

EGNSS Yes



The Belgian Viapass system started operations on 1 April 2016 and is managed by Satellic NV. The programme collects tolls on behalf of the Flemish, Walloon and Brussels-Capital regions on motorways and some regional and municipal roads.

The use of OBU is mandatory and must be switched on whenever using a Belgian road. The OBU works with the 'thin client' approach, which was chosen to allow for EETS provider participation from the very beginning on Viapass' Toll domains. Currently, five EETS providers are approved (Axxés, Eurotoll, Satellic, Telepass, Toll4Europe and Total), with three others in the process of accreditation (MSTS, TollTickets and WAG).

The scheme accounts for some 750,000 OBU in the field, with about 144,000 different trucks travelling on Belgian roads every day, for an average of nearly 25 million km, which translates into some €2.7 million in tolling revenue and an annualised revenue of around €814 million (2021).

Regarding enforcement, less than 1% of trucks drive without OBU. Viapass, together

with the BIPT and the traffic police, organise checks on OBU usage of special vehicles and on the use of GNSS jammers, for which heavy fines apply.







The Viapass system has been very successful so far as the main goals set by the three regions have been achieved.

- Viapass is in its 3rd year of flawless operations
- 6 Service Providers (1 SPP + 5 EETS) are part of the system, with more filing for accreditation
- Broad choice for fleet owners, according to needs and service model
- More green vehicles and traffic (70.5% of EURO 6 trucks in 2020, up from 45% in 2017)

“Belgium is a success story for electronic tolling in general and for EETS in particular. It provides best practices to be followed by other Member States. Viapass has been instrumental to this success.”
- Violeta Bulc (European Commission’s Commissioner for Transport)



BULGARIA

	Start of activities Q2 2020		Registered Vehicles c. 80,000 (in late 2020)
	Target Vehicles HGV with 3.5+ tonnes		Annual Tolling Income c. €230 mln (expected)
	Total Kilometres 3,115 km (803 km motorways and 2,312 km 1 st class roads)		EETS Providers Toll4Europe, TollTickets

EGNSS Yes



In late 2015, the World Bank, which supported Bulgaria's Road Infrastructure Agency (RIA) in conducting a detailed study on options for a RUC scheme, released a report concluding that a GNSS-based tolling represented the most viable option. Specifically, it noted that the best system would somehow replicate the Hungarian model, which does not mandate the installation of a specific OBU and allows for different toll declaration providers and the use of a pre-paid route-pass or toll ticket.

The contract for building the system was awarded in 2017 and included a GNSS-based RUC solution for vehicles above 3.5 tonnes and the electronic vignette system for passenger vehicles.

The Bulgarian system (BGToll) is innovative because, for the first time, the contractor developing the system does not provide OBU to road users but instead only installed the central system and enforcement infrastructure. It is also unique in that it anticipates, at least in the mid-term, the combination of EETS with fleet management.

As per RIA's requirements, the OBU must support Galileo, GPS and GLONASS, as well as EGNOS.

As of March 2020, vehicles with a mass exceeding 3.5 tonnes are required to pay a charge based on the travelled distance on some 3,115 km, of which 803 km are motorways and 2,312 km are first-class roads.

The automatic payment for using the road is done by means of a contract concluded with any of the Toll Declaration Data Providers (DDP). Currently, there are 23 DDPs, all of whom are registered with one of the two national service providers (NSP), who also provide the e-vignettes.

The route is recorded by a tolling-specific OBU or by an already installed fleet management device, with the latter being possible only if the company offering the fleet management service has a contract with an NSP.







The DDP transmits positioning data to the NSP in a format suitable for processing and which the NSP transmits to the RIA's central system. The device for satellite positioning should be certified by the DDP according to the requirements of the NSP, as well as the requirements of RIA.

As in the case of Hungary, because the OBU is not mandatory, enforcement is done by means of an ANPR in stationary cameras and mobile control units, which recognises the license plate numbers of the vehicle, detects its passage and, after verification in the central system, registers the correct or incorrect use of the paid road network.

In economic terms, with the current toll network, some €230 million in revenue is estimated from the HGV RUC scheme and some €150 million from electronic vignettes.



CZECH REPUBLIC

 Start of activities 1 December 2019	 Registered Vehicles c. 643,000 with 75% from abroad & c. 530,000 OBUs (2021)
 Target Vehicles HGV with 3.5+ tonnes	 Annual Tolling Income €571 mln (14.198 CZK mln, 2021) ¹
 Total Kilometres 2019: 1,500 km 2020: 2,400 km	 EETS Providers None

EGNSS
Yes



Together with the Slovak company SkyToll, CzechToll (PPF Group, Czech Republic) has designed, built and operates the country's electronic toll system. The system is based on GNSS and mobile communications and DRSC for enforcement and started operations on 1 December 2019, with the contract running until 2030.

This system replaces the former one based on DSRC, showing how GNSS has become the preferred technology for HGV tolling. Some of the DSRC gantries previously used have been recycled as part of the new GNSS system for enforcement purposes. From an economic perspective, the government expects that the operation of the new system will be cheaper than the former, by as much as €35 million per year.

Following an expansion of the toll road network, the toll now applies on a total of 1,102 kilometres of 1st category roads and 1,307 kilometres of motorways. At the start of operations of the new system, there were some 319,000 vehicles registered. As of 2021, that number is 643,000, of which a quarter are Czech vehicles.

CzechToll is highly flexible and can be quickly implemented, and the cost of building it has been significantly lower than other technologies. This new GNSS toll system







¹ Exchange rate as of 31-DEC-2021: 1 EUR = 24.87 CZK

gives the government the flexibility to change the range of toll roads and simply set different toll rates for different road categories. In addition, data from the system can be easily used for additional superstructure applications, such as traffic intensity management, the efficient planning of maintenance and investment in transport infrastructure.

The OBU is provided by Billien (who also provides the OBU in Slovakia) and is a more cost-effective version featuring backlit symbols instead of a display. In this sense, almost all the deployed OBUs in the Czech scheme are EGNSS-enabled.



GERMANY

	Start of activities 1 January 2005		Registered Vehicles c. 1,2 mln
	Target Vehicles HGV with 7.5+ tonnes		Annual Tolling Income €7.2 bln (2020)
	Total Kilometres 2005: 14,000 km 2015: 15,100 km 2018: 52,000 km		EETS Providers Toll4Europe, Telepass, Axxes, Total

EGNSS Yes



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 15 years in operation, it has delivered outstanding flexibility and reliability, allowing for two expansions of the road network without service disruption.

The system evolved from the initial 14,000 km (2005) to 15,100 km (2015). As of 2018, the toll road network consisted of 52,000 km, which today provides an annual revenue of €7.4 billion to the toll charger, the Federal Ministry of Transport and Digital Infrastructure.

This road network expansion was accompanied by the inclusion of some 600 enforcement pillars on federal trunk roads to supplement mobile enforcement and as an evolution of the normal gantries on motorways. These enforcement pillars feature similar technological capabilities as gantries and check whether passing vehicles are subject to a toll and whether toll charges were properly paid.

Besides the expansion of the toll network in 2018, there was a substantial change to the automatic log-on process as the approximately 1.1 million OBUs installed







back then were gradually converted from a decentralised to a centralised system for toll collection in a so called 'thin client' approach. This was done through firmware upgrades. The OBU now sends time-delayed and encrypted journey data, along with relevant vehicle features, to the Toll Collect computer centre, where the toll for the route sections that the truck travelled on is computed. This change made it possible for EETS providers to start operations in Germany. Currently, three EETS providers are approved (Toll4Europe, Axxes, Total Energies and Telepass).

The updated system also allows for differentiating the toll according to weight classes, configurable through the OBU. Starting 1 January 2019, in addition to the costs of noise pollution, the truck toll is calculated on the basis of emission class, weight class and, for vehicles over 18 tonnes, on the number of axles.

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



HUNGARY

-  **Start of activities**
1 July 2013
-  **Registered Vehicles**
c. 435,000 (c. 260,000 w. OBU)
-  **Target Vehicles**
HGV with 3.5+ tonnes
-  **Annual Tolling Income**
c. €836 mln (2019)¹
-  **Total Kilometres**
2013: 6,500 km
2019: 6,900 km
-  **EETS Providers**
Toll4Europe, Telepass

EGNSS
Yes (some TDO)



The Hungarian HU-GO system is managed by National Toll Payment Services PLC (NTPS) on behalf of the State Motorway Management Company and started operations on 1 July 2013 with a network of around 6,500 km (currently 6,900 km). Its launch was an important step towards open RUC schemes, which subsequently led to innovative value-added services with respect to other GNSS-based RUC solutions found on the market (e.g. fine alert service when non-compliance is detected, mobile application for ticket purchasing and vehicle data update, etc.).

Despite being the most convenient way to pay tolls, the use of an OBU is not mandatory in Hungary (i.e. a route ticket is used instead). As such, enforcement is done by means of ANPR only, a substantial difference among many other GNSS RUC schemes in operation, which use DSRC for this purpose.

The operational cost for the Hungarian tolling system amounts to only about 9% of the total toll revenue. One of the key drivers of such cost-efficiency is that NTPS allows for fleet management solution providers to participate as Toll Declaration Operators (TDO). This is because some responsibility of a well-functioning system is transferred to the TDO, as they must comply with stringent requirements in terms







¹ Exchange rate as of 31-DEC-2019: 1 EUR = 330 HUF

of position accuracy (94% accuracy within 15 minutes, 99.94% accuracy after five days and 100% accuracy after 25 days). Currently there are 22 accredited TDOs,

Currently, there are 22 accredited TDO and most rely solely on GPS for positioning. Although there have been some minor issues related to inadequate tolling, in general, results have been satisfactory enough for NTPS purposes. However, an important provider of robust GNSS-based OBUs tested its equipment and obtained an outstanding 99.8% accurate reporting within 15 minutes using an EGNSS-enabled OBU. Considering that 1000+ penalties are issued per month due to incorrect declarations, the use of better positioning systems such as Galileo is important.



POLAND

	Start of activities 24 June 2021		Registered Vehicles c. 1.63 mln
	Target Vehicles HGV with 3.5+ tonnes		Annual Tolling Income €490 mln
	Total Kilometres c. 3,670 km		EETS Providers EETS providers approval process initiated

EGNSS

Yes



In late 2018, responsibility for operating the DSRC-based National Toll Collection System was transferred from the General Directorate for National Roads and Motorways (GDDKiA) to the General Inspectorate of Road Transport (GITD). Soon after, the Ministries of Infrastructure and of Digitisation jointly announced the creation of a completely new toll system, replacing the former DSRC-based system with a GNSS-based one. The Polish Institute of Communications, a national research institute supervised by the Ministry of Digitisation, was appointed to develop the new concept and using the existing ViaTOLL DSRC-based infrastructure installed back in 2011 for enforcement purposes.

In June 2020, the President signed an amendment to the act on public roads, providing for a change from a DSRC to a GNSS tolling system for national roads. One interesting point of this amendment was that drivers can use either a dedicated OBU or a mobile device with a special application installed that can be downloaded free of charge.

The new e-TOLL started operations in June 2021 on some 3,700 km of roads. It is an advanced solution for collecting tolls from vehicles driven on toll sections of roads

in Poland under the management of the GDDKiA. It allows users to choose the most convenient method for transmitting location data to the system: either using a free application installed on mobile devices, via an external location system mounted in the vehicle (ELS), or using an OBU.







OBUs and ELS units are available from a distribution network where allowed companies (positively scored in the e-TOLL system testing) are published on the e-TOLL website, somewhat like Hungary's HU-GO system. Furthermore, because the distribution and sales model has an extensive choice of legal options (e.g. a deposit, sale or rental), an OBU or an ELS can be obtained on free market terms.

The mobile device application enables the payment of tolls, recharging and monitoring the account balance, as well as fulfilment of obligations of carriers of sensitive goods in the SENT-GEO system.

EETS will also be accepted in Poland and the accreditation process of the first EETS providers is ongoing.



SLOVAKIA

 Start of activities 1 January 2010	 Registered Vehicles c. 288,000 (mandatory OBU)
 Target Vehicles HGV with 3.5+ tonnes	 Annual Tolling Income c. €231 mln (2021)
 Total Kilometres 2010: 2,450 km 2014: 17,700 km 2021: 8,231 km	 EETS Providers -

EGNSS Yes



From 1 January 2010, SkyToll has operated one of the largest toll systems in the world, putting Slovakia among the leaders in electronic toll collection. The system was completely built and commissioned in only 11 months and currently covers around 8,231 kilometres of specified sections of motorways, expressways and first, second and third-class roads.

The scheme combines the advantages of GNSS location technology, DSRC for enforcement and mobile communications. GNSS was selected thanks to its significant advantage over other road charging technologies in terms of the flexibility for implementing new requirements, managing increases in traffic volume and expanding the toll road network.

Initially, the system covered almost 2,400km of roads, but was expanded to some 17,700 km back in 2014. This expansion took just three months' work carried out by Skytoll, and the subsequent deployment of a OBU software update. This expansion led the National Motorway Company to request accurate traffic information about HGVs over 3.5 tonnes on the roads, which they used for better planning and allocation of resources for the repair and construction of new roads. This traffic information is

also used by other entities (e.g. by customs officers, to detect fake exports abroad and related tax evasion).

The system is technologically ready for interoperability with neighbouring countries and in compliance with the requirements of EETS. However, there are currently no EETS providers active in the Slovak toll domain.







As of the end of 2021, c. 288,000 OBU were registered, of which almost three quarters correspond to foreign vehicles. All of SkyToll's OBUs support EGNOS and nearly half include a Galileo-enabled chipset for a more robust positioning determination.

Starting on 1 September 2020, several third-class roads were removed from the network of specified road sections. After these adjustments, the length of the network of specified road sections dropped from 17,600 km to 8,141 km. Thanks to the versatility of a GNSS-based system, this change was possible with a simple software update.

The current operations contract is due to expire at the end of 2022. As such, the Slovak national motorway company (NDS, Národná Diaľničná Spoločnosť) started a procurement process in late 2020 to purchase a new GNSS-based tolling system to be operated by NDS, rather than contracted, owned and operated on its behalf, as is the case today. The intention of a country already using GNSS to upgrade its system with the same technology speaks clearly of the well-understood benefits offered to RUC by satellite technologies.



SWITZERLAND

	Start of activities 1 January 2001		Registered Vehicles 55,000 (domestic) 3,000 (foreign)
	Target Vehicles HGV with 3.5+ tonnes		Annual Tolling Income c. €1.3 bln (estimated)
	Total Kilometres 71,500 km (c. 1,800 km of highways)		EETS Providers Telepass, Toll4Europe

EGNSS

Yes (EETS providers' OBU)



The transport policy that has been in force since 1985 in Switzerland aims to transfer a large part of the country's freight transport from roads to rail, thus protecting the natural environment and the alpine landscape from the impact of excessive HGV traffic.

In 2001, the Swiss RUC scheme (Heavy Vehicle Fee, HVF) was the first to use GNSS to monitor the recording of the tachometer, as well as to determine whether the unit is in Switzerland or abroad. The Heavy Vehicle Charge (LSVA in German) is a federal levy based on the total weight, emission class and kilometres travelled in Switzerland and the Principality of Liechtenstein for vehicles weighing more than 3.5 tonnes.

After almost two decades of use, the benefits of using a GNSS-supported system are clear. During this time, the RUC scheme has provided low operational costs (around 5% of revenue), while HGV traffic crossing the country has been reduced and the road transport of goods has become more efficient, with an overall positive benefit for the environment.

Vehicles registered in Switzerland are required to use the purpose-fit OBU (i.e. Emotach) that determines the exact mileage based on the signal transmitted by the tachometer. Foreign vehicles can use an ID card and a special terminal at each entry, allowing them to personally declare the kilometres driven in the country prior to leaving its border.

In 2018, the Swiss government awarded a contract to modernise its roadside and central toll system, as well as to expand the function of the systems to allow for EETS interoperability within the DaziT project.

Technically speaking, a new recording service was established and integrated into the existing Swiss toll system. On the infrastructure side, the beacon and enforcement systems along the Swiss road network and at border crossings were converted. In addition, a new organisational solution for the implementation of EETS was designed and tested. The Swiss Federal Customs Administration (FCA) now works with EETS providers, which have to undergo a four-stage approval procedure before they can offer their services in Switzerland, in line with the procedure established in the EU.






At the end of March 2020, the technical solution for EETS use was rolled out to the customs office, making it possible to automatically record the distance travelled and pay the fees using OBU from accredited EETS providers. On January 2021, the first official EETS journey to Switzerland took place. According to the roadmap for the DaziT transformation programme, the system will also replace the existing Emotach recording system for domestic vehicles by early 2024.

Interoperability is not completely new within the Swiss tolling scheme. As a DSRC sub-system, Emotach has been compatible with both the Austrian (ASFINAG) and Italian (Telepass) tolling systems for several years now. However, the recent ability to use a GNSS OBU demonstrates how versatile this technology is as it allows for tolling in an all-roads scheme (i.e. some 71,500 kilometres of roads and highways) with very low investment.



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

DENMARK (PLANNED)

 Start of activities 2025	 Registered Vehicles -
 Target Vehicles HGV with 12+ tonnes (estimated)	 Annual Tolling Income c. €140 mln (estimated)
 Total Kilometres At least 1,100 km (current Eurovignette, estimated)	 EETS Providers Open to EETS Providers from the beginning

EGNSS
Yes



Denmark is one of the Eurovignette countries with HGV weighing more than 12 tonnes paying a flat, time-based fee for using all motorways and highways (c. 1,100 km). Moreover, all vehicles pay a toll (either in cash or using the DSRC BroBizz tag) when passing two major bridges: the Storebælt link (18km long) and the Øresund link (16km long) connecting Denmark and Sweden, for which there are c. 1.3 million users.

As part of its climate change policy to reduce emissions by 70% by 2030, the Danish Government announced in December 2020 that it will introduce a GNSS-based RUC scheme for HGV.

The intention is to introduce the new system starting in 2025, which will replace Denmark's participation in the Eurovignette scheme. The objective of the new RUC scheme is to improve incentives for transitioning the heavy vehicle fleet towards lower emission vehicles. However, it will be designed to also reflect the impact these vehicles have on infrastructure and road wear costs, along with their noise impact.

Although there are no clear indications yet, if the new system follows Eurovignette's lead, it will be applicable to Danish and foreign registered HGV of > 12 tonnes. Eurovignette's revenues are around €67 million at present and it is the government's intent that the new system keep the same revenue level until 2027, and then double it from 2028 onwards.

The Danish government estimates that the costs for establishing and operating the system will be comparable to systems implemented in the past. This is in line with the huge advancements in technology and market maturity of GNSS telematics OBUs, mobile communications and enforcement equipment that have happened during the last decade.

The project is being managed by Sund & Bælt, a Danish government-owned company responsible for Storebælt and Øresund links. The company will be responsible for implementation and operations, as well as enforcement of the new system.

From a technical standpoint, a GNSS OBU (around €150 including installation) will be mandatory, with an option for cheaper self-installed OBU. As such, it seems that, eventually, no manual or pre-paid ticket option will be available.

From a planning standpoint, procurement and delivery commenced in mid-2021 and will continue until early 2024, with preparation and operation of testing and commissioning happening from early 2023 to early 2025. A first step in the procurement process as already initiated and Sund & Bælt have engaged in dialogues with suppliers with experience in and the ability to deliver and maintain technical solutions within distance-based tolling based on GNSS. This approach aims to address, prior to issuing the public tender, aspects such as the GNSS data handling, map and toll context data and map-matching/segment identification and toll calculation, among other issues.

FRANCE (PLANNED, REGIONAL)

	Start of activities Mid 2025 (estimated)		Registered Vehicles -
	Target Vehicles HGV with 3.5+ tonnes		Annual Tolling Income €200-300 mln (estimated)
	Total Kilometres -		EETS Providers Open to EETS Providers from the beginning

EGNSS

Yes (EETS providers' OBU)



Although Ecotaxe, the French nation-wide 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 some regions of the country. The argument is that doing so would be a natural extension of the Belgian and German ETC systems, as the regions see a lot of freight traffic diverting from these neighbouring countries with HGV toll roads in place.

In particular, the European Collectivity of Alsace (CEA in French), which was established by law ('CEA Law') in August 2019, received ownership of roads and highways not conceded and previously held by the French State and located on its territory, the A35 being one of the most important. Furthermore, it has been empowered to take any measure regarding specific contributions paid by the users concerned to control the traffic of goods. It has also been authorised to set a tax on goods transport vehicles that use the road.

During this legal process, in January 2021, the CEA published a prior information notice informing all potentially interested operators of the organisation of a prior market consultation, to inform them of the characteristics of the project, and to collect feedback from the industry.







In May 2022, the CEA launched a tendering process for the procurement of a GNSS-based RUC system, which included, among other things, the design, construction, operation, upkeep and maintenance of a toll collection system (and its respective enforcement), including a solution for occasional road users to make a declaration specifying the characteristics of their vehicle and their journey (i.e. 'ticketing').

The contract with the selected company will be signed for a period of eight and a half years (102 months) and broken into two periods: a development period, with a provisional duration of 18 months, followed by an operating period of 84 months. The signature is expected in October 2023, meaning the system should be ready by mid-2025.

This imminent introduction of GNSS for RUC in the eastern most part of the Grand Est region could cause other parts of the region to implement a similar solution, considering that traffic diversion is currently in place or likely to be implemented. In Lorraine, for example, the A31 fulfils this condition, particularly the Thionville-Metz-Nancy axis. Several officials from Lorraine were also in favour of taxation on this motorway, considering a very likely shift in HGV traffic as soon as the RUC scheme on the A35 comes into force.

It is estimated that in the Grand-Est region, a regional RUC scheme could generate between €200 and 300 million per year. This is also one of the regions that did not dismantle the enforcement gantries from Ecotaxe. The choice of technology for the renewed implementation of an HGV tax is clear, as most neighbouring countries (e.g. Belgium, Germany, Switzerland and, soon, the Netherlands) already use GNSS for RUC.

LITHUANIA (PLANNED)

 Start of activities 2023-2024	 Registered Vehicles -
 Target Vehicles All freight vehicles and buses from 8 passengers onwards	 Annual Tolling Income 110 € mln (estimated)
 Total Kilometres c. 1,700 km (major highways)	 EETS Providers Open to EETS Providers from the beginning

EGNSS
Yes



In 2015, the Lithuanian Road Administration (LRA) carried out a study to estimate investments and operational costs for installing a RUC scheme on roads of national significance with DSRC- or GNSS-based solutions. Moreover, during that year and in just 15-days time, SkyToll implemented an electronic toll collection solution demo on 353 kilometres of motorways, national and regional roads in the country to showcase the benefits of using GNSS for RUC.







Soon after the study, the intention of implementing a distance-based system, replacing the time-based one, was evident. After some years under political discussion, in late 2020, the Lithuanian Parliament approved amendments to the Law on Financing of the Road Maintenance and Development Program, which foresee funds to develop, implement and maintain a road charging system. In March 2021, the LRA issued a tender for the “Development of the Electronic Road Toll Information System” but the tendering process was temporarily interrupted and it resumed some months later with deadlines on February and March 2022 for the enforcement equipment and the complete toll system, respectively.

The new tolling system is expected to be implemented within 16 months after signing the contract, with two months for testing and two months for test operation, thus starting in late 2023 or 2024. The tolled road network will include all major highways (some 1,700 km) and will apply to all freight vehicles and buses having more than 8 passenger seats. Freight vehicles of less than 3.5 tn are included, as a key difference with respect to other European countries.

The nationwide tolling system will rely on the full interoperability with the EETS from the start of operations. The procurement should include the development and implementation services of the tolling system, the functionality and maintenance services for five years and also consulting services for ETC modules and functionality. The Ministry of Transport foresees a pay-back period of three years .

The tender focus on OBU software requirements, and not hardware, while EETS providers should be accepted from the beginning with a strong focus on the use of smartphones (see also the chapter BYOD - BRING YOUR OWN DEVICE: SMARTPHONES USE FOR RUC), as another key difference with other European countries using GNSS for tolling and in line with what is already implemented in Poland. All in all, smartphones, telematics devices and dedicated OBUs will be accepted in Lithuania.

THE NETHERLANDS (PLANNED)

 Start of activities 2024	 Registered Vehicles c. 850,000 with 85% from abroad (expected)
 Target Vehicles HGV with 3.5+ tonnes	 Annual Tolling Income €650 mln (expected)
 Total Kilometres c. 6,000 km (estimated)	 EETS Providers Open to EETS Providers from the beginning

EGNSS
Yes



As of 2024, HGV and tractor units with trailers weighing 3.5 tonnes or more will pay for the number of kilometres driven and recorded on chargeable roads. The exception will be vehicles that are not primarily intended for freight transport (e.g. farming and forestry tractors, mobile cranes, buses, military vehicles and public service vehicles).

The HGV toll will be in force on all the motorways in the Netherlands, along with a number of regional and local roads to deal with diverted traffic. No HGV toll will be enforced on roads that are already subject to toll payment (e.g. the Liefkenshoek tunnel).

The toll levied will depend on a truck's environmental features: the cleaner the truck (euro class), the lower the toll. The more kilometres driven by a truck, the higher the toll to be paid. The Dutch government's objective is to encourage the sector to opt for cleaner trucks, more efficient logistics and the use of other modes of transport such as ship and rail.

The Netherlands' main highway network (hoofdwegennet) consists of most of the country's 5,200 km of national roads, together with the most prominent

provincial roads. Although only about 2,700 km of roads are fully constructed to motorway standards, much of the remainder are also expressways. The length of the Dutch road network to be priced is estimated at around 6,000 km and the motorway network alone has more than 600 slip roads, making pricing based on GNSS technology the best choice.

The scheme requires a GNSS OBU and a contract with a toll service provider. From the operational perspective, the government aims for a small Main Service Provider (MSP). It also intends to allow EETS providers to be part of the system from the beginning. Users who are required to pay the charge but are unwilling or unable to conclude a contract with an EETS provider may use the MSP which, in addition those offered by an EETS provider, will provide additional services such as the issuing of on-board equipment at the border. In order to ensure the greatest possible competition between EETS providers, users will not be able to use the MSP's on-board units on a cross-border basis.

The OBU will determine the vehicle's position and communicate it to the TSP via mobile communication. Based on the rules for the TD, the toll service provider will calculate the tolls payable for the distance driven. The TSP will collect the charges periodically by sending an invoice to the licence plate holder and will remit the amounts received to the government. In terms of privacy, the OBU will only process data about the vehicle's location and time and not data about the driver. A government digital enforcement (DSRC and ANPR) system will check whether vehicles possess the correct on-board equipment, are complying with the rules and are not engaging in fraudulent practices.

In addition to RUC for HGV, the government intends to introduce RUC for all (electric and combustion) LCV/PC by 2030, which would track the distance travelled on all roads in the country and allow for rates charged to vary by emissions rating.

NEW ZEALAND



Start of activities
1978 (RUC)
2012 (eRUC)



Registered Vehicles
c. 165,000 HGV (43,000 w/ eRUC)
and 715,000 LCV (22,000 w/eRUC)



Target Vehicles
HGV with 3.5+ tonnes
& light diesel vehicles



Annual Tolling Income
c. €900 mln



Total Kilometres
c. 6,000 km (estimated)

EGNSS

No

The cost of using New Zealand's roads is recovered from users via levies on the price of some fuels and through RUC. The revenue collected from road user charges is dedicated to the National Land Transport Fund and are collected by the NZ Transport Agency (NZTA) and enforced by the New Zealand Police.

The current Road User Charges Act came into force on 1 August 2012. This act simplified and modernised the national RUC system and reduced compliance costs for businesses. It also simplified administration processes for both industry and government by using modern technology for the administration and collection of RUC.

All diesel-powered vehicles and those powered by a fuel not taxed at the source, regardless of weight, along with vehicles weighing more than 3.5 tonnes, are required to display current road user charges licences while operating on public roads. This license is paid in advanced to actual road usage and is based on the vehicle's RUC weight and RUC vehicle type.

HGVs weighing more than 3.5 tonnes must be fitted with an approved hub-odometer (a device mounted on the axle that measures the distance travelled) or an approved

electronic distance recorder (EDR) based on GNSS.

There are currently four approved EDR providers that act as RUC agents for the New Zealand Transport Agency. eRUC (i.e. EDR-based RUC) is mainly used by HGV fleet operators, although uptake by light vehicle fleet operators is increasing due to the value-added services provided by GNSS. Around 26% of HGV and 3% of light diesel vehicles use eRUC, which now collects over half of all RUC revenue.

The OBU (EDR) measures distance travelled with a high degree of accuracy. It does this using a combination of internal and external sensors, including vehicle data, GNSS and micro-electrical-mechanical systems (MEMS). EDR providers offer similar solutions, in compliance with the NZTA, along with a range of other value-added services for fleet management.

Unlike most European OBUs for GNSS-based tolling (e.g. Continental, Siemens, Billien, etc.), New Zealand's OBUs present large graphical touchscreens, which also provide VAS. The main eRUC providers in New Zealand have operations in the USA for the Electronic Logging Device (ELD).



UNITED STATES OF AMERICA



Start of activities

Utah: 2020
Virginia: 2022
Oregon: 2025



Registered Vehicles

Utah: low (voluntary basis)
Oregon: 400,000/ year (from 2025)



Target Vehicles

Utah and Virginia: optional for EV or hybrid
Oregon: mandatory for all new vehicles



Annual Tolling Income

Utah: N/A
Oregon: N/A



Total Kilometres

Utah: 134,000 km
Virginia: 93,000 km
Oregon: 126,000 km

EGNSS

One of the most widely used OBD-2 devices uses Galileo

The federal highway and public transportation programmes in the United States are funded mainly by taxes on motor fuel. The tax rates, set on a per-gallon basis, in general, have not been raised since 1993. Increases in vehicle fuel efficiency and the wider use of electric vehicles raise questions about the long-term viability of motor fuel taxes as a means of funding surface transportation.

In this sense, economists have long favoured distance-based user charges as an alternative source of highway funding. In fact, some states have charged trucks by the distance driven for many years now. Recent technological developments (telematics), as well as the evident shortcomings of motor fuel taxes, have led to renewed interest in the user charge concept, with Congress even providing the required funds for large-scale RUC pilots through the 'Fixing America's Surface Transportation Act' (FAST Act).

In terms of HGV, the US Federal Government has recently mandated the use of Electronic Logging Devices (ELDs), with the aim of creating a safer work environment for drivers and to make it easier and faster to accurately track, manage and share records on duty status data. This mandate impacts some 4.3 million truck drivers that will use telematics devices with GNSS on-board. Although not intended for RUC, considering the bottom-up approach used by individual states, in which paying for RUC in an automated way is only one service among many provided by the telematics device, there could be a great and easy uptake of RUC in the country.

A particular initiative for passenger vehicles is RUC West, which includes 17 state transportation organisations who share resources to investigate RUC methods to achieve economies of scale in their projects or research. Of these states, two have already enacted a policy to implement RUC (Utah in 2020 voluntarily and Oregon from 2025 mandatorily via its 'OReGO' programme). Four others have pilot programmes running. Although the pilots are not mandated to be based on GNSS, the acceptance of OBD-2 dongles with GNSS capabilities is, in general, over 60% due to the convenience it offers drivers. In accordance with the spirit of EETS in Europe, RUC West's aim is that systems developed in the USA will allow drivers to select one reporting and account management option and travel throughout the country without the need for different technologies or paying separate bills.

More recently, Virginia launched its 'Mileage Choice' programme in July 2022. The programme offers EV or hybrid vehicle owners the choice of paying for the distance driven instead of a flat annual registration fee. Distance is measured through an OBD-2 device, with an initial odometer reading captured with a smartphone app.



INDIA (PLANNED)



Start of activities
2023 (expected)



Total Kilometres
Potentially 130,000 km



Target Vehicles
All vehicles

India has an operational National Electronic Toll Collection (NETC) called 'FASTag' supplied and deployed by the publicly-owned Indian Highways Management Company Ltd. (IHMCL). The system is based on RFID technology with c. 720 electronic toll plazas across the country. FASTag was introduced in 2016 to replace cash payments and was made compulsory in February 2021, reaching 30 million users by March 2021. Because vehicles without FASTag have to pay double toll fees at electronic toll plazas across the country, its uptake rate is very high at c. 93% of vehicles. Although traffic delays have been dramatically improved thanks to FASTag, they still occur, since traffic slows down at the toll plazas to pass the RFID lanes.

Following a successful pilot study on the Delhi-Mumbai corridor of some 1,400 km, India's Ministry of Road Transport and Highways announced plans in December 2020 to remove all toll plazas on highways throughout the country within two years and replace them with GNSS technology. This change makes sense considering the National Highway Authority of India (NHAI) is responsible for c. 130,000 km of highways and is rapidly building and expanding the network at a pace of 36 km per day and that congestion at toll plazas is still commonplace even with the current cashless scheme.

To address the rapid growth of the highway network and the significant increase in traffic, there is a growing need to eliminate congestion at toll plazas. As already practiced in several European countries, GNSS-based tolling solutions provide a cost-effective means for establishing distance-based ETC on national road networks without the need for extensive roadside infrastructure.

The plan, which was presented in late 2020, foresees the introduction of the new system by 2023. India's own regional navigation system (NavIC) is expected to be used for the new system to provide better accuracy than GNSS-only solutions, giving

it even more impetus for nationwide adoption. However, a GNSS-based solution would also help to address speeding, which is an issue on some of the most important highways.

FASTag already makes toll collection automatic, with the charges deducted directly from a user's linked bank account. However, before it can be implemented, there are concerns from some political factions regarding enforcement and privacy, which will need to be addressed, along with the storage and processing of geolocation data. NHAI has already made it a priority to ensure that data captured and transmitted is stored safely and securely, while also being instantaneously accessible by the tolling systems.

In terms of the OBU, the Indian government stated that new commercial vehicles currently being rolled out already have the necessary technology (i.e. fleet management OBU) and only needs to be activated. The government is working on how to implement this on older vehicles.

NHAI opened a tendering process in April 2021 for the technical consultancy to develop a roadmap on how this new and ambitious tolling system can be built. The process will assess, among other things, the system's technical requirements, potential complementation between the current RFID system and the future GNSS one, the road infrastructure needed, legal impacts, etc. Once India launches its new GNSS-based tolling system, it will become the largest tolling system in the world in terms of kilometres covered.

INDONESIA (PLANNED)



Start of activities
Late 2022 (expected)



Total Kilometres
1,700 km (and up to 6,000 km)



Target Vehicles
All vehicles

The current length of the Indonesian archipelago's toll road network is 1,713 km, with a scheme for tolling based on 2,115 toll plazas operated by 48 concessionaires. The toll road network is planned to exceed 6,000 km in the coming years, making the current scheme unviable and unsustainable.

Moreover, traffic jams are a huge problem in Indonesia and, according to the government, the country loses around €3.8 billion annually because of generalised traffic jams in urban zones and at highway toll plazas.

In April 2020, a comprehensive study from a consulting company supporting the government concluded that the introduction of a free-flow toll collection system could save anywhere from half a minute up to 5 minutes per transaction, depending on the length of the queue. This alone justifies the need for such a system. In addition to a substantial savings arising from reduced travel time, the introduction of a free-flow toll collection system may result in savings in toll collection costs through modern e-payment methods that offer flexibility and convenience to all users.

The new toll collection system will also provide economic benefits related to higher traffic flow, lower capital expenses and lower operational expenses. For this reason, the study recommends implementing a GNSS-based scheme in which drivers can use their own devices (e.g. smartphones) as an OBU, for the following reasons:

- The ability to locate and track a vehicle in space and time enables the differentiation of a scheme regarding distance, time and place and implementation on nationwide, high density road networks, including all vehicle and road types.
- The low costs for expanding the system allows one to employ area-wide tolling systems (inter-urban tolling) to prevent possible traffic rerouting, which may cause serious environmental and social problems.

- Once the tolling system is established, the OBU can be used for additional purposes, including value-added services that may create opportunities for new business projects.
- Unlike DSRC, RFID and ANPR, very little roadside infrastructure is needed for enforcement.
- It may serve as a basis for Jakarta's ERP (Congestion Charging scheme) and parking payment solution without having to construct extra roadside infrastructure.

In 2021, the government awarded the Hungarian company Roatex, the contractual partner of Nemzeti Útdíjfizetési Szolgáltató Zrt. (NÚSZ Zrt.), a 10-year contract to build and operate the new GNSS-based system, which is expected to start in late 2022.

The project will result in an investment of around €285 million and is one of the largest Hungarian technology exports ever. The first phase of the project covers the deployment of the system and is expected to take one and a half years.

FINLAND

Finland does not currently operate any road tolls. Instead, funding for roads comes from vehicle taxes. However, the government has conducted several studies over the past decade to evaluate the introduction of RUC for HGV, LCV and PC. Although some decisions were taken, plans for implementation were not accompanied by any practical deployment.

In 2011, the Transport Ministry supported the implementation of a national RUC scheme capable of charging not only according to time and location (to charge for congestion) but also according to public transport availability (e.g. it would be more costly to drive if the route had a parallel metro line than in a remote area). It was also decided that GNSS would have been the underlying technology for such scheme, but there public acceptance was lacking.

In early 2014, an extensive study on 'Fair and Intelligent Transport' in the country stated that a distance-based tax would be a more flexible transport policy tool than the current tax system because 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 be better able to achieve transport and environmental policy objectives than the existing tax regime. It would reduce passenger car use, emission levels and road accidents while also increasing the use of public transport. GNSS was the preferred technology for such a scheme. Public debate on this topic revealed a lack of understanding amongst policymakers, which experts found difficult to overcome, particularly as concerns short vs. long term effects. This, along with unfounded negative press about privacy issues, ultimately meant that these renewed plans for a RUC scheme were left on hold.

The topic once again entered the agenda in late 2019, when the recently appointed government published its programme, part of which was related to reforming transport taxation. Legislation will be proposed to allow for traffic congestion charging to be introduced in city regions, with the aim of managing traffic, reducing congestions and supporting climate change initiatives.

GREECE

Greece has a toll motorway network of some 2,130 km. This network is operated by eight private companies, of which seven concessions have a non-free-flow DSRC tolling system, with some 830,000 subscribers of both commercial and passenger vehicles.

The case for GNSS-based tolling for commercial vehicles was clearly understood by the national authorities. Recently constructed motorways (i.e. Egnatia Motorway) with toll booths were part of a planned electronic tolling system. This system was considered to be significantly more just as it would have charged vehicles based on the distance covered in the entirety of the country's motorway network.

In early 2018, an initial expression of interest for a GNSS-based toll system in Greece was launched, with companies from both Greece and other European countries forming five different consortia, out of which two remained as bidders.

The tendering process continued and bids were put in place in 2019. However, the process was stopped indefinitely in May 2020 due, in part, to the complexity of the complete solution requested by the Greek Government, on a single procurement process, to include GNSS (HGV and LCV), ANPR (PC) and RFID (all vehicles) – the latter for enforcement and border security reasons. Various economic and political reasons also contributed to the sudden stop and to the reluctance of some stakeholders to change the existing system and ETC subscriber base without a clear, phased-based migration path.

Fortunately, the cancellation of the tender has not stopped innovative concessionaires from incorporating smart technologies for value-added services and, in the short-term, for tolling as well. In fact, a smartphone app was made available to Olympia Motorway users in the spring of 2020. The app provides trip planning features, weather and incident forecasts, virtual tours, emergency calling, location-based personalised information functions, traffic prediction information and a fee-based messaging system. For ETC subscribers, the app also enables users to manage their account, including invoice information and real-time account reloading. A future version of the app will offer a lower cost, more friendly and reliable tolling system.

ITALY

Italy has a network of some 6,600 km of interconnected tolled highways managed and operated by 'Azienda Nazionale Autonoma delle Strade' (ANAS), which also oversees some 20,000 km of non-toll roads.

For the tolled network, there are around 25 concessionaires (5,500 km of highways under concession) and 8 million ETC subscribers. All vehicles pay, either cash at toll booths or with non-free-flow DSRC (UNI 10607 standard), operated in Italy by Telepass up to 2016 and, since then, also by EETS providers from abroad.

The Italian ETC technology of choice has always been DSRC with toll plazas. However, new technological solutions are under study by ANAS, within the framework of the major national-level project 'Smart Roads', which has the goal of leading Italy towards digitally transforming more than 2,500 km of roads and highways. The first phase of the project was procured in 2018 on the A2 'Autostrade del Mediterraneo'.

ANAS has already concluded that a GNSS-based system is well suited for the taxation of its large road network. Considering the overall 12 million OBUs estimated, ANAS aims to take a phased approach that will exploit the versatility of a GNSS system, allowing ANAS to start charging HCV at an early stage and introduce PC and LCV once the system is operating smoothly and the public has understood the benefits of distance-based taxation.

NORWAY

The Norwegian Government charges vehicle owners taxes on fuel purchases, vehicle registrations and toll roads. These taxes are supposed to cover the cost of building and maintaining Norwegian roads, and they are supposed to be fair for everyone.

However, there are two problems with this approach. On one hand, the government collects less money from fuel taxes due to more fuel-efficient vehicles and the fact that electric vehicles are increasing their market share every year (more than 80% of new car sales were fully electric or hybrid in 2021). On the other hand, the Norwegian population is increasingly frustrated by constantly increasing, unfair toll road fees, which has triggered protest marches and even the creation of a new political party.

In this sense, most political parties in the Norwegian Parliament are in favour of exploring RUC as a replacement of toll roads, to be applied to the use of all roads in the country, not only certain ones. In particular, the Norwegian Institute of Transport Economics suggests that RUC should be dynamic and vary based on

a vehicle's environmental footprint and axial load, as well as the area (e.g. population density) and time (e.g. rush hours) a vehicle is driving. A GNSS-based system would meet these requirements (i.e. all roads and area and time of driving), and the Norwegian Research Council is funding pilot projects to build and test technical RUC solutions. One of them, Pilot-T ASAM, is testing a RUC solution on real vehicles across the country with the goal of "providing a fair and accurate tax solution" with a combined usage of C-ITS and GNSS.

While today's tolling systems in Norway are based on passages through gantries (DSRC), the GeoFlow proof of concept from Q-Free has a distance and fuel differentiated RUC scheme. By using an OBU and a smartphone app, the driver gets instant information about the cost of driving and can plan journeys by using parameters such as hour and zone to get an overview of the pricing of different alternatives. A dynamic pricing system with higher costs during rush hours and urban zones helps regulate traffic, further reduce congestion and enable more environmental, economic and socially sustainable driving patterns.

After several smaller pilots, the project is now conducting tests at a larger scale, with at least 200 volunteer drivers testing the system.

Given the maturity of the tolling industry in Norway, there is an ongoing 'toll reform' in which a new organisational structure is envisioned, moving from 60 toll companies to five regional toll companies owned by the counties (i.e. Regional Authorities) and separating the toll service providers from the toll charger, in line with the EETS directive.

PORTUGAL

Pilot tests of the Satalise app, the initiative of Spanish Cintra and GMV for GNSS-based smartphone app for toll payments, kicked off in August 2020 in Portugal. The pilot involved real users on the A-28 highway, which runs for 119 km along the northeast coast of the country.

The application, already in commercial use in Catalonia, was designed with the idea of using smartphone-based satellite positioning technology for pay-per use tolling without the need for gantries or any additional infrastructure. Under this system, users only need to sign up to the system and enable the app on their smartphones. The system then taps into the phone's satellite positioning capacity to detect the vehicle's passage through a series of virtual toll gantries or zones, thereby triggering the toll collection process just as if the vehicle had passed through a real booth.

GNSS-BASED ROAD USER CHARGING

Before being used in Portugal, the app had to be type-approved by the relevant authorities as a payment method (like a credit card or DSRC device). After the successful completion of the internal tests and granting of the required approval, tests have been launched with end users.

Successful results could mean the start of an alternative GNSS-based payment solution in a country where most toll highways are based on microwave (i.e. DSRC) solutions.

ROMANIA

In Romania, vignettes are required for all roads and for all vehicles. However, the government has plans to introduce a comprehensive ITS system, which may see the introduction of RUC as one of the services. The recent implementation of two national GNSS-tolling schemes (Bulgaria and Hungary) triggered strategic discussions among private/public stakeholders on the convenience of introducing a nation-wide tolling system fully interoperable with these neighbouring countries.

SPAIN

A network of toll plazas exists in Spain, operated either manually at toll plazas (in a closed tolling scheme) or automatically, using a 'Via-T' box (DSRC). Spain has one of the most extensive highway networks in the world, spanning over 17,000 km. Just over 3,000 (around 18%) roads in the network are toll highways, on which all vehicles are required to pay, with some 4.7 million subscribers of ETC. There are numerous concessions, under the membership of SEOPAN (Association of Construction Companies and Concessionaires of Infrastructures).

Several institutions in the country, like SEOPAN and the Spanish Road Association (AEC), have been calling for a nation-wide tolling scheme for years. The ongoing debate on an eventual change in the current management model of the highways includes aspects such as the maintenance of the network, environmental sustainability, and the traffic spill-over of HGV drivers who use free alternative lower-class roads, generating traffic problems and potentially more accidents.

The suggestion of charging for the use of Spain's high-capacity roads has been on the Ministry of Transport's agenda since 2018. Furthermore, as a consequence of the COVID-19 pandemic, the government included the introduction of tolls in the national recovery plan it sent the European Commission. In fact, in May 2021,

the Spanish government was planning to introduce a payment mechanism on the country's high-capacity roads starting in 2024, by which drivers would pay to use the network of highways and high-speed motorways, which are currently free of charge. The plan also opened the door to charging a fee on other national and regional roads.

The vast size of the Spanish tolled road network, which could also include national and regional roads, positions GNSS as a well-suited technology to be used for RUC. The current socio-economic situation (post-pandemic inflation, global geopolitical conflicts) has however meant that this initiative has been temporarily put on hold.

So far, the lack of a national decision has led some regions to implement a local RUC scheme, such as Gipuzkoa, which set up a scheme based on DSRC for HGV on some 70 km of highway. The main reason behind this decision was the heavy traffic from foreign vehicles which do not contribute to the maintenance of the roads they use. Although this technology makes sense for such a short strait, it is not sustainable in the long term, nor is it the best fit for a potential nation-wide scheme.

In a more innovative fashion, the company Cintra implemented Satelise, a GNSS-based smartphone app that facilitates toll payments on highways. It allows for electronic payment without the need for an OBU installed in the vehicle. The app aims to match what ANPR systems installed at toll stations detect when the vehicle passes through. This helps reduce the cost of manual image inspection. The first implementation was in the Catalonia region on some 40 km of highway where toll plazas have a dedicated free-flow line (without barriers) for Satelise users. As a result of this initiative, such GNSS-based solutions may be implemented in other concessions, even in other countries (e.g. Satelise in Portugal).

SWEDEN

Sweden is currently a Eurovignette country, although research by different stakeholders on adopting a new RUC scheme has been underway for several years. For instance, the ARENA project, running from 2006 to 2018, conducted extensive field trials and published several reports. The conclusion was that the new RUC scheme should depend on vehicle characteristics, driven distance, classification of road segments used and the time of day and should cover all public roads.

The main reason for this suggestion is that the country has a sparse population and relatively few vehicles using an extensive road network and a small share of motorways and expressways. Instead, because secondary roads often are of good condition, they offer almost the same average speed as motorways, especially for

HGV. This calls for extensive coverage of the road network if tolling is to be efficient, otherwise the shift of traffic to non-taxed roads would be significant. These facts indicate a clear advantage for GNSS as the suitable technology.

In February 2017, a government commission in charge of a study on a distance-based RUC scheme for HGV released a report. Its main considerations and recommendations were that such a scheme should:

- Cover national and municipal roads and streets and should apply to HGV > 12 tonnes, which translates into some 78,000 Swedish HGV (as per the vignette) and c. 100,000 foreign HGV that would be subject to toll;
- Be based on GNSS with flexible measurement methods for measuring the distance driven, in which tolerance levels are prescribed that determine the maximum allowed deviation in accuracy of measurement;
- Route information should preferably stay with a private actor chosen by the taxpayers themselves and that the transfer of information to the authorities should be minimised. A very large percentage (approximately 85%) of the vehicles deemed to be taxable already have technical equipment (FMS) that can be used to transfer the information to a service provider; and
- Route tickets should be offered to make the system more user friendly for infrequent users and temporary visitors.

The proposals stemming from the study are to be carried forward by the Ministry of Finance. A further study on the design of a new environmental management system as an alternative to the current time-based toll for HGV was published in March 2022. This study concluded that a distance-based system must be the alternative to the current time-based system, given it has a greater chance of taking into account Sweden's special geographical conditions and also allows for differentiation on:

- The taxable road network: those roads with a traffic intensity of less than 500 heavy vehicles per 24-hour period are exempt from taxation, which can even be calculated dynamically;
- Geography: suburban and urban areas are easily accounted, with the possibility of a higher tax on urban areas; and
- Vehicle characteristics: based on the registered details of the vehicles.

Moreover, the new distance-based environmental tax system would better support compliance by HGV traffic on Swedish roads.

In terms of the network subject to the RUC scheme, there are doubts as to whether

it will apply to the complete network or only to the 2,100 km of European roads (e.g. E4 and E6), 13,565 km of national roads and the primary regional roads. With this big network and the small number of vehicles (some 200,000), the case for GNSS is clear in Sweden.

UNITED KINGDOM

In the United Kingdom, there is currently minimal road tolling, limited to certain major pieces of transport infrastructure (e.g. the M6 highway of around 40 km and some bridges in London).

Plans to introduce GNSS road tolling for all vehicles in the country were announced by the Transport Secretary as far back as 2005, with prices based on congestion. These plans were supported by numerous credible studies from British institutions. However, in 2007, an online petition against road pricing garnered over 1.8 million signatures, the equivalent of 6% of the UK driving population. As a result, all such plans were terminated.

Given the problem of traffic and road deterioration, especially from foreign HGV, has continued on the UK's roads, the "HGV Road User Levy Act" was established in 2013 and went into effect in April 2014. It is based on the electronic vignette approach (ANPR-enforced and time-based system) and is applicable to local and foreign-registered lorries weighing more than 12 tonnes using any of UK public roads. However, the expected behavioural change did not occur. Whereas the Department for Transport (DfT) expected less HGV traffic due to the annual levy, only 1.9 million levies were purchased, almost all of which (91%) were daily levies.

Structural changes in the Highways Agency took place back in 2015, with the aim of making it easier, quicker and simpler to get UK infrastructure to grow. The act allowed for the creation of Highways England, a government-owned company that can access the long term, stable funding needed to deliver the government's roads investment strategy, which includes new Intelligent Transport Systems (ITS) infrastructure.

Apart from the levy to HGVs, in the UK there was also consideration of a levy on PC/LV driving on Britain's motorways and main roads. The idea behind this thinking was to unlock investment in the aging highway network by giving more independence to the Highways Agency for turning roads into a regulated utility, run by a company or companies with a dedicated funding stream from motorists.

Debate is still ongoing and with renewed interest, partly because of the anticipated

GNSS-BASED ROAD USER CHARGING

changes to travel over the next 20-30 years and the common policy aim of all major UK political parties to decarbonise road transport and the implications of such a policy. Further, local and central governments are facing a perfect storm of poor air quality in towns and cities, the adoption of ultra-low emission vehicles (ULEVs) and their long-term impact on car tax and excise duty, and the need to tackle congestion and its impacts. Together, these factors have created a new climate in which some sort of pricing for road use may not only be possible, but acceptable.

Whether the government opts for a national RUC scheme for HGV or all vehicles based on the distance travelled, it is clear that the solution should be based on GNSS as road-side infrastructure for DSRC or ANPR for tax collection (i.e. not only for enforcement) would be technically very difficult to achieve.

AUSTRALIA

The Australian Government recognises that charging by registration fee and fuel tax, as is done today, is inefficient and results in significant infrastructure costs and cross subsidies among heavy vehicle road users. For this reason, since 2015, it has been working on the 'Heavy Vehicle Road Reform', which aims not just change how heavy vehicles (trucks and buses) are charged, but also how those charges are set, how revenue is used and the basis for planning how to spend that revenue.

Some independent studies from important consulting firms recommend the use of GNSS technologies, as is the case of New Zealand, since it could be a platform for further reforms in charging and funding arrangements (e.g. differential rates for particular road types or targeting a particular corridor or area congestion issue).

In 2019, a six-month pilot was held involving some 200 HGV with 4.5+ tonnes using GNSS-enabled telematics devices. Later, between 2020-2021, some 1000 HGV participated on an 18-month pilot using telematics devices with the objective of comparing the current running costs for business against the ones from the RUC scheme.

Furthermore, electric PC/LV RUC schemes are established (Victoria) and planned (New South Wales and Western Australia). However, for the moment, these would be based on odometer readings with a smartphone and not a telematics device. In any case, an OBD-2 or vehicle-mounted telematics device might be a clear way forward in the mid-term.

KAZAKHSTAN

In the framework of extensive road construction and widening projects in Kazakhstan, supported and funded by the European Bank for Reconstruction and Development (EBRD), the Kazakh Government needs to explore more sustainable ways for road financing and maintenance. These include the introduction of charges for heavy vehicles and the rollout of a tolling system.

In this sense, the EBRD published a request for expression of interest for a Public-Private Partnership (PPP) on the design, implementation and operation of a tolling system on public roads. Private partners were asked to use both their own and raised funding to create, design, upgrade and maintain the tolling system on public roads, totalling some 15,000 km during a period of 13 years.

An important aspect was the request for the use of innovative technologies for a high-tech tolling system software with open input code containing no proprietary components. The software was to be specifically designed for the purposes of the project, with the exclusive ownership rights to be transferred to the Republic of Kazakhstan under the PPP contract. Free-flow tolling system based on GNSS technology was envisioned as one of the possibilities, which makes sense, considering the size of the envisioned toll road network.

Approximately one third of Kazakhstan's roadways will be subject to toll charges by 2022, which is around 7,000 km out of the 23,000 km of national roads.

UKRAINE

Road transport has long played an important role in Ukraine's domestic and international transport sectors. Between 2012 and 2016, the share of international trade by value handled by road transport in the country increased from 30% to 37%, an increase that coincided with a shift in international trading patterns away from the Russian Federation and towards the European Union.

In late 2015, the World Bank approved a €0.5 billion loan to finance the Road Sector Development Project in Ukraine. This financing supports a number of measures to improve road network management, transport connectivity, maintenance operations and road safety for drivers in the country.

Ukraine has 47,000 km of main roads (i.e. excluding local roads). However, despite the road sector's importance, investments in road maintenance are very low compared to other countries in the region (less than 1% of GDP).

Ukravtodor, the State Agency of Automobile Roads of Ukraine, considers funding shortages as the root cause of problems with the road system. Without reform, the condition of Ukraine's roads will continue the deterioration that saw the share of roads in poor condition increase from 5% to 17% between 2011 and 2016.

For this reason, the Ukrainian Government adopted legislation for the creation of a new Road Fund, which came into effect in January 2018, to deliver significantly more funds to the road sector.

Along with the many kilometres of roads that will be enhanced with the funding, this operation supports the legal and institutional reforms necessary to improve the country's road network management by supporting the preparation of relevant legislation and documents to finance, install and operate a national system for tolling, weight control for HGV and automatic speed enforcement.

In mid-2019, after the Weigh-in-Motion (WiM) and speeding and traffic analysis systems were put in place, Ukravtodor made clear its intention to introduce the toll system for HGV as the fourth part of the overall ITS plans, and it is currently designing a road pricing scheme for foreign HGV that weigh 12 tonnes or more based on GNSS.

According to Ukravtodor, the implementation of the GNSS system on international roads will make it possible to receive additional annual revenues of around €260 million to the Road Fund and the payback period would be about one year, with a profitability of around 80%.

Apart from tolling, the GNSS system would make it possible to implement complete control over passenger traffic and special equipment (e.g. garbage trucks), as well as the transportation of dangerous, valuable or special goods, ultimately making the transportation market more transparent.

The invasion of Ukraine by the Russian Federation in early 2022 has prevented any further progress in the implementation of a GNSS RUC scheme.

URUGUAY

Uruguay collects tolls using a close approach with barriers at toll plazas using RFID technology. Given that toll roads do not apply to the complete network, many vehicles subject to the payment are able to avoid the small number of toll plazas (traffic diversion) and thus avoid paying tolls altogether.

Considering the high level of HGV traffic from neighbouring countries Argentina and Brazil, the Uruguayan government is currently looking for a more efficient tolling solution that could also allow it to monitor transport throughout the country.

Back in 2016, and in only two months, SkyToll from Slovakia conducted a pilot project for RUC on some 8,200 km of roads of different categories in Uruguay.

The electronic toll system tested used an OBU from SkyToll, which entailed GNSS, GSM/GPRS communication and RFID for compatibility with existing stop-and-go toll gantries. The chosen toll collection technology provided the maximum flexibility to manage future growth of cargo transport volume, as well as the expansion of the road network in Uruguay.

In early 2021, the Ministry of Transport and Public Works was evaluating several modifications to the tolling scheme. The most straightforward was the modification of the tolling scheme for HGV to start paying for the distance driven using GNSS and also taking into account the weight of the HGV load at the moment of using the road by means of a weight sensor on-board the HGV.

In case this project advances, Uruguay would become the first country in South America to adopt GNSS-based RUC.

GNSS-BASED CONGESTION CHARGING



There have been several studies and field tests on the use of GNSS as a means of implementing Congestion Charging (CC) schemes for PC/LV in Europe and worldwide. Field tests aimed at obtaining knowledge and experience on the use of GNSS technology for CC were and are currently conducted in different cities in which congestion is a major problem.

Singapore, which has conducted such studies and field tests, finally decided to implement a GNSS-based system for PC/LV, with deployment ongoing. Other cities mentioned in this section (Melbourne, Brussels, Vancouver, Jakarta and London) still have not ruled for using GNSS as a means of CC, not because of technical or economic reasons, but instead for reasons related to political resistance, legacy systems already in place or a lack of public support.

Public (and subsequent political) support is key for successful CC initiatives. Acceptance has thus far been poor due to two main reasons:

1. A lack of willingness to pay for the distance driven. However, there have been cases like the CC in Stockholm where acceptance of the system increased from 52% to 75% after the system was implemented and when communities had enough time to fully understand the benefits.
2. Privacy concerns, as a result of low awareness on how localisation technologies work, was once a more prominent concern. However, thanks to the acceptance of other In-Vehicle Systems (IVS) based on position determination like eCall or the widespread use of smartphones for numerous location-based services, the concern over privacy has largely been overcome.



Although in the case of CC, each city evaluating the use of GNSS has its own particular needs, limitations and stakeholders involved, the evolution in technology, decrease in the cost of embedded electronics and the ubiquitous presence of smartphones all allow GNSS-based schemes to move closer to implementation. This would allow discrimination in tariffs/ fees by taking into account such factors as time, distance travelled, congestion state, etc.

EXISTING AND PLANNED SCHEMES WORLDWIDE

SINGAPORE

The Republic of Singapore is a modern city-state and island country in Southeast Asia. With a population of around 5.5 million, it ranks third in the world with respect to population density.

This fact has made Singapore the pioneer on using DSRC-based schemes for Congestion Charging (CC) purposes, which it started doing in 1998. However, in October 2014, the Singaporean Government decided to replace its DSRC-based Electronic Road Pricing (ERP) system with GNSS positioning technology. The new scheme was initially planned to charge motorists for the distance they drove on congested routes rather than levying a flat fee to enter an electronic road pricing zone, as per the existing system. However, in 2020, the Land Transport Authority (LTA) announced that when the actual switch to the GNSS-based system takes place in mid-2023, the existing cordon-based congestion pricing framework will remain, but with the advantage of no longer having big gantries .

The decision to switch from DSRC to GNSS came after several studies, the results of which convinced the LTA that the GNSS-based system was technologically feasible. The main drivers for the decision to use it were:

- Growing cost of maintaining the DSRC gantries;
- Possibility of using variable charging as a means of being more equitable for motorists:
 - o discounts for off-peak use, and
 - o discounts for choosing uncongested roads;
- Possibility of added-value services:
 - o electronic payment of parking charges, and
 - o location-oriented real-time traffic information.

GNSS-BASED CONGESTION CHARGING

The new OBU has two designs: a one-piece unit for motorcycles and, for other vehicles, a more complex, three-piece device comprising of an antenna, a touchscreen display to be mounted on the windscreen and a processing unit, which can be mounted beneath the dashboard and has a slot for payment cards. The new OBU for vehicles other than motorcycles is overly complex as per compatibility requirements with the current ERP system and carparks. The LTA is studying whether data from the new OBU in vehicles can be pushed to smartphones, allowing them to be used as an alternative display screen for ERP information. Once the system is working smoothly, LTA will look at replacing the display or the OBU with a smartphone.

Regarding the deployment of the system, the supply of essential microchips, which is required for the OBUs, has been affected by the global shortage. To ensure a smooth and uninterrupted installation exercise for all motorists, the installation of OBUs is now planned to commence in the second half of 2023.

POTENTIAL SCHEMES WORLDWIDE

AUSTRALIA (MELBOURNE)

In 2016, Transurban, a road operator company that manages and develops urban toll road networks in Australia, Canada and the United States, conducted a RUC study in Melbourne, which was the first real-world test of user-pays road charging in Australia.

The study captured the responses of 1,635 private light vehicle motorists from the Greater Melbourne region on five user-pays charging options.

It was designed to meet three objectives:

- Gauge motorists' knowledge and understanding of the current road-funding system and assess their attitudes and preferences toward user-pays charging options.
- Understand motorists' behavioural responses to different charging and implementation options.
- Prove that technology is not a barrier to implementing a practical user-pays system.

Two road-charging models with distinct purposes were tested consecutively:

- Usage-based model: this model tested participant responses to a user-pays funding approach that is more transparent and sustainable as a funding source. Three usage-based charging options were tested: charge per kilometre, charge per trip and flat rate (capped kilometres).

¹ GNSS-based system for passenger cars in the BCR, PhD. Maxime Uhoda, Senior Researcher at the Tax Management Directorate (FIS) of Bruxelles Fiscalité, RUC Conference 2020.

- Congestion-based model: this model tested how motorists responded to demand-management pricing signals to reduce road use in highly congested geographies or at peak travel times. Two congestion-based charging options were tested: cordon (area) and time of day.

The study showed a user-pays road-funding model will work in Australia and can provide a sustainable, fair and flexible funding system that grows with demand. With acceptance rates of 60% for the user-pays system on top of the current system and of 84% on GNSS-based solution, it is clear that a potential urban scheme in Melbourne or other cities in the country will use this technology for reporting distance travelled.

BELGIUM (BRUSSELS)

In the EU, road charges may be complemented by an 'external cost' charge, which aims to reduce pollution from road transport. Thus, EU Member States may also modulate the infrastructure charge to take road congestion into account.

In Belgium, the Regional Tax Administration implements the Brussels Capital Region's (BCR) competencies in terms of mobility, including the circulation and car registration taxes, the Brussels Low Emission Zone, the tax on the operation of taxis or cars with driver and the kilometre charge for HGV (Viapass).

Car tax revenues in the BCR, which include the Annual Circulation Tax (ACT) and Car Registration Tax (CRT) are in the order of €185 million, of which 23.5% comes from leased vehicles. In this context, it is estimated that the number of vehicles in the region is 1.2 million (55% Brussels inhabitants, 35% from other regions and 10% from other countries).

With the aim of allowing for better use of cars whilst avoiding a negative social impact, the BCR intends to implement intelligent, kilometre-based charging for light vehicles. Doing so will limit traffic congestion, particularly at peak times. The current circulation tax regime as it relates to this objective is being reviewed and the new scheme will build on its technology. The BCR's intention is to move from an annual lump sum (car tax) towards an intelligent system in which the rate is determined by the number of kilometres travelled, at what time, with which car and on which route. At the same time, people will be fiscally rewarded if they use public modes of transport.¹

By October 2020, a project dubbed SmartMove had designed a new tax model. This tax model, which still requires political agreement, is based on a basic rate per day of use, plus a kilometre component, which varies according to peak and non-peak hours and according to the fiscal power of the vehicle. Technically, SmartMove would

be based on a mobile application for recording the distance travelled and manage payments, while ANPR would be used for enforcement.

The system was initially expected to go live in 2022, but the political decision has been delayed until 2024 (next legislature).

CANADA (VANCOUVER)

In Canada, tolls are not common as, across the entire country, there are only 18 routes subject to toll. More so, only two of them are roads, while 12 are bridges or tunnels on the Canada-U.S. border.

However, some provinces, such as British Columbia, are evaluating the introduction of tolls as a method for coping with the lack of funding and the increased traffic congestion near big cities like Vancouver.

In fact, Metro Vancouver, a federation of 21 municipalities that collaboratively plans for and delivers regional-scale services, appointed a 'Mobility Pricing Independent Commission' (MPIC) that is tasked with figuring out how a new transit plan would work.

The study, which was released in mid-2018, outlined two possible options for road mobility. The first is based on regional congestion point charges in which 12 major crossings throughout the region would become a static charge point, supposedly by means of DSRC, RFID or ANPR. As for the second option, drivers would be charged by the distance they travel based on zones defined throughout the region.

In mid-2021, the City of Vancouver issued a request for proposals to conduct a feasibility study on a 'road use fee' in the city centre based on a variety of factors, including vehicle type, time of day and traffic congestion. This follows the 2018 report from the regionally-focused MPIC, which concluded charging road tolls would be the most effective tool for reducing regional congestion. Based on the timeline by MPIC, after further study by TransLink and the development of a policy, mobility pricing could be implemented in the region by the mid-2020s.

INDONESIA (JAKARTA)

The capital city of Indonesia has plans to introduce an ERP scheme similar to the one used in Singapore. Jakarta has a population of about 10 million and has huge traffic congestion problems, which translate into high economic losses for society.

In this respect, the government aims to implement a CC scheme and, although the tendering process has been running for years now, the city has yet to determine which technology it would use.

Until now, the most favoured has been DSRC. However, recent developments at national level for a GNSS-based road user charging system could cause the city to opt for this technology, a decision that would allow economies of scale, in coordination with the national government.

In late 2021, the Jakarta provincial government drafted an ERP policy for the capital city roads that aims to reduce the use of private vehicles in order to overcome congestion in the capital city and increase public interest in using public transport, as well as tackling air pollution. The policy looks to implement the system on 18 streets (nearly 174 km) of the city by 2039. This plan is to be discussed in 2022, although there is no indication of the technology to be used.

UNITED KINGDOM (LONDON)

The City of London is looking for solutions to tackle congestion, air pollution and to generate funds to maintain the roads of Greater London. In the summer of 2020, due to the pandemic, talks were held between Transport for London (TfL) and the Department for Transport (DfT) about a bailout, which emphasises the impact a collapse in passenger fares makes on the TfL's finances.

Among the bailout conditions requested by the government is that the £15 congestion charge (CC) be extended to the north and south circulars, which would affect 3 million Londoners and 540,000 journeys a day. This is likely to be highly unpopular amongst the affected population.

Several stakeholders are therefore examining more sophisticated alternatives (i.e. based on distance and time of day), given the current technology is 20 years old and relies on cameras to enforce a flat-rate fee, no matter the distance driven.

In July 2020, the Mayor for London said TfL is investigating whether there are ways to better reflect distance driven, emissions, time and road danger in a smart and fair system, as new technologies (like GNSS-based telematics OBU or smartphones) could offer the potential for more sophisticated models of paying for road use in the longer term. A distance-based charge with a flat fixed fee (like that being studied for Brussels) seems to be the best solution, which could be trialled using such telematics systems already built into some PC/LV and HGV or smartphones.

EMERGING TRENDS



Tolling devices can take different forms and be issued by different players, as the Hungarian and Bulgarian RUC schemes demonstrate. The list of examples will likely increase in the near future as such schemes are capable of delivering or integrating tolling services. Such devices can be **line-fitted** (i.e. by the Original Equipment Manufacturer, or OEM), mounted as **aftermarket solutions** (e.g. tolling OBU, fleet telematics box) or even correspond to a **Bring Your Own Device (BYOD)** setup (i.e. by using a smartphone with GNSS and connectivity).

For line-fitted devices that have GNSS capabilities, there are OEM systems, eCall devices, Smart Digital Tachographs and Event Data Recorders (EDR). Aftermarket devices include tolling OBU, On-Board Diagnosis (OBD) dongles and telematics boxes.

As many of these devices are already becoming popular in the electronic tolling industry, they will likely drive mid-term trends as outlined in the following sections.

CONVERGENCE OF RUC AND FLEET TELEMATICS

Fleet telematics continues to grow at a rapid pace across Europe and worldwide. Some of the devices used for telematics are already being certified as tolling devices across a growing number of TD.

A natural step forward for GNSS-based RUC schemes has been the utilisation of electronic equipment, initially for the management of fleets, as a toll declaration solution for HGV. In this respect, the Hungarian HU-GO system has been a pioneer, together with a similar solution in New Zealand, where EDR devices based on GNSS are used to declare kilometres driven and provide value-added services to fleet owners.

In the specific case of Europe, until recently, the combination of a Fleet Management Service (FMS) with a tolling service was exclusive to Hungary. However, Hungary's system has influenced the design of other national tolling systems (e.g. Bulgaria) and the carrying out of comprehensive studies (e.g. Ukraine).

Using the approach taken for the system deployed in Bulgaria, local FMS providers and international EETS providers would be able to act as TSP. A further step is possible, similar to the Belgian Viapass scheme, in which from day one, there were options to select EETS providers.

Meanwhile, another disruption is taking place: more EETS providers are providing value-added services (e.g. tracking and tracing, parking payment, etc.). Well-established EETS players are now providing telematics services with their GNSS OBU

(e.g. Telepass with KMaster service in Italy or Axxes in France). Furthermore, new EETS providers on the market who have limited experience with electronic tolling services now have expertise in offering services to fleet owners (e.g. Eurowag from the Czech Republic, which developed a new OBU and IT system) and are offering FMS services (including Tacho readings).

Experienced FMS providers are well-positioned to extend their service portfolio, including EETS services, and it is possible that they will also become EETS providers. From the freight forwarding companies standpoint, the establishment of EETS across Europe and the availability of FMS offered, in combination with tolling services on a single platform, is good news as this could significantly reduce their operational costs.



EMERGING TRENDS

SMART TACHOGRAPH USE FOR RUC

The European Tachograph System for Commercial Vehicles has been operating since 1985. It is mandatory in all EU and European Free Trade Association (EFTA) countries according to the AETR agreement (European Agreement concerning the work of Crews of Vehicles engaged in International Road Transport).

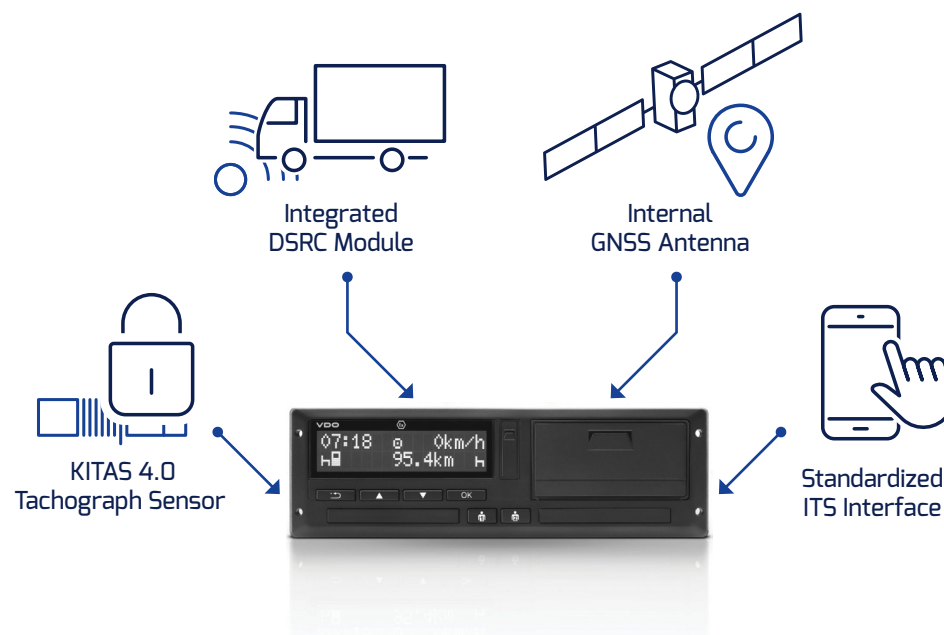
Since mid-2019, the EU Tachograph Regulation (EC) No. 799/2016 makes Smart Tachographs mandatory for European goods transport. It also requires that the corresponding next generation of Smart Tachographs include future-oriented GNSS capabilities and DSRC, as well as substantially enhanced telematics and monitoring system interfaces to facilitate compliance with road traffic law throughout Europe.

The Smart Tachograph is a key element of a broad range of vehicle system architectures for future digital trucks. It sets new standards for secure and comprehensive control systems in commercial vehicles in terms of the transport of live animals, EETS road tolling, road safety systems and integrating commercial value-added services.

Future mobility services that continuously monitor freight and optimally use infrastructure will efficiently support transport and logistics service providers as well as generate new business opportunities in the field of digital value creation. Efficient data generation from vehicle sensor technologies – and its real-time analysis – will become integral elements of the logistics business.

In the specific case of tolling, the advantages of using a Smart Tachograph for RUC would be:

- Factory approved installation: integrated Smart Tachograph and ETC tolling functionality under a unique device (i.e. repeatable performances);
- No installation issues or costs: loose electrical installation and touch/shock vibration can lead to intermittent electrical contact, causing reliability issues. Devices are installed by OEM's, fully integrated into the vehicle;
- No extra devices on windscreen: no add-on boxes on windscreen required (better safety);
- Better antenna reception for DSRC and GNSS: for both types of tolling technologies, the antennas will likely better located than on a windscreen OBU;
- Secure and accurate positioning with OSNMA capability;
- Easier maintenance: fewer subsystems to maintain; and
- Lower total cost of ownership: as the TSP does not have to buy a dedicated OBU or incur in installation costs.



BYOD – BRING YOUR OWN DEVICE: SMARTPHONES FOR RUC

National TSP have argued for years that direct control over the OBU ensures greater reliability and accuracy of the service. Despite this, there has been general disapproval of open device models (e.g. the Hungarian HU-GO system). However, this is starting to change, as can be seen in Bulgaria's decision to opt for an open system, the introduction of a smartphone app in Poland (see figure below) and, in the near future, in Lithuania.

The lack of direct control over the device has also been used as an argument against using smartphones to collect road charges. However, advancements in positioning capabilities, better battery life, more reliable network communications and EU-wide roaming all lend support to the use of smartphones for RUC. Innovative solutions have already started to appear.

GNSS-enabled smartphones are used in the USA by GeoToll to allow drivers to travel through any partner electronic toll facility without cash or using a particular transponder (e.g. RFID). Furthermore, in Europe, GNSS-based smartphone apps for tolling are being used on Spanish highways in Catalonia and are being tested in Portugal (i.e. Satelise from Cintra/Ferrovial). In Austria, Kapsch, one of the main tolling products providers, provides a solution based on ANPR and aided by a smartphone app.

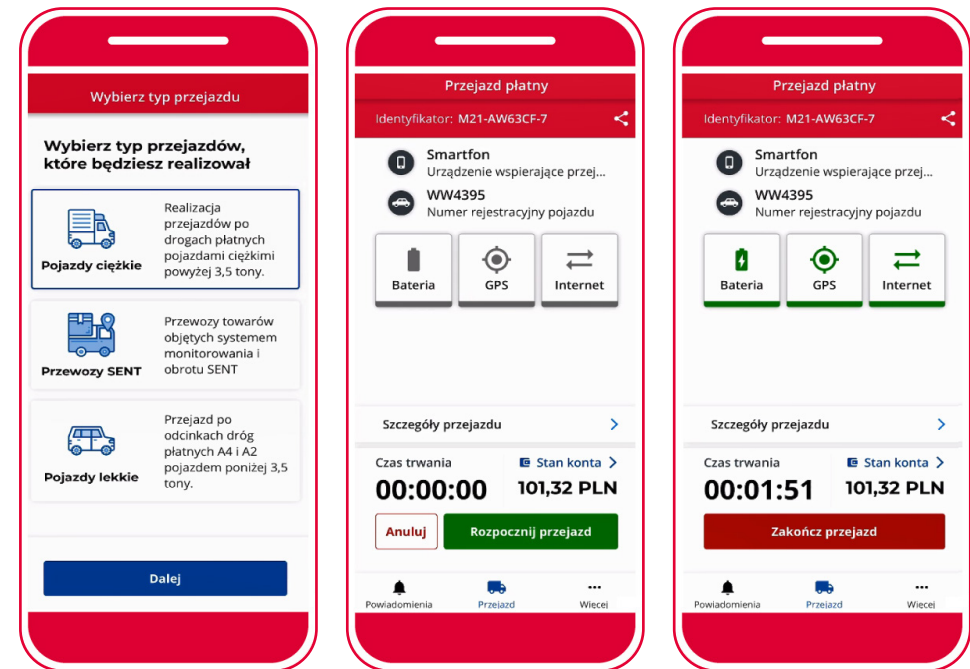
These products are not actually open road distance-based tolling solutions and are instead used as a way to automate payments at toll booths with barriers, eliminating the need of a DSRC OBU. There are more advanced solutions being explored that combine the flexibility of a smartphone with the enforcement possibilities of DSRC for distance-based tolling.

Norbit, a Norwegian company providing ITS solutions, together with T-Systems from Germany, have developed a cost-efficient solution for distance-based tolling as a response to European Commission's intent to mandate the replacement of time-based charges for HGV with a second stage also involving PC, which may be charged by the distance travelled. As of now, DSRC is not feasible for tolling a country-wide network due to the huge infrastructure costs, while GNSS with a dedicated OBU is not suited to very high volumes like PC due to the high cost and volume.

The innovations happening at these companies come in the form of a smartphone tolling application that is used in combination with DSRC OBU and paired via a Bluetooth Low-Energy (BLE) connection. The app tracks the driven route using GNSS built into the smartphone, communicates with the central system via a mobile network and interacts with the road user via an HMI, while the DSRC device is used to communicate with roadside infrastructure for enforcement or tolling in DSRC TD.

Such a solution would work all around Europe, both in countries with pure DSRC tolling and in countries using GNSS tolling. In the first case, the DSRC OBU handles tolling transactions while, in the second case, the DSRC OBU handles enforcement.

The use of apps on smartphones for BYOD is a natural next step in the evolution of RUC. Furthermore, smartphone app-based tolling is an important prerequisite for PC in roads and city tolling.



ACRONYMS

Acronym	Description
AEC	Asociación Española de la Carretera (Spanish Road Association)
AETIS	Association of Electronic Toll and Interoperable Services
ANAS	Azienda Nazionale Autonoma delle Strade (Italy)
ANPR	Automatic Number-Plate Recognition
ASECAP	European Association of Operators of Toll Road Infrastructures
BCR	Brussels Capital Region (Belgium)
BIPT	Belgian Institute for Postal services and Telecommunications
BLE	Bluetooth Low-Energy
BYOD	Bring Your Own Device
CC	Congestion Charging
CDR	Charge Data Record
CEA	Collectivite Europeene d'Alsace, European Collectivity of Alsace
CN ADNAR	Romanian National Company of Road Infrastructure Management
DfT	Department for Transport (United Kingdom)
DSRC	Dedicated Short Range Communications
EDAS	EGNOS Data Access Service
EDR	Event Data Recorders
EFTA	European Free Trade Association
EGNOS	European Geostationary Navigation Overlay Service
ELD	Electronic Logging Device
ELS	External Location System (Polish e-TOLL)
ERP	Electronic Road Pricing (mainly used in Singapore)
eRUC	EDR-based Road User Charging (New Zealand)
ETC	Electronic Toll Collection

EU	European Union
EUCARIS	European Vehicle and Driving Licence Information System
FAST Act	Fixing America's Surface Transportation Act (in the United States)
FMS	Fleet Management Services
GDDKiA	General Directorate for National Roads and Motorways (Poland)
GITD	General Inspectorate of Road Transport (Poland)
GNSS	Global Navigation Satellite System
HAS	High Accuracy Service (Galileo)
HGV	Heavy Goods Vehicle (more than 3.5 tonnes)
HVF	Distance-related Heavy Vehicle Fee (Switzerland)
IHMCL	Indian Highways Management Company Ltd.
ITS	Intelligent Transport Systems
LCV	Light Commercial Vehicle (up to 3.5 tonnes)
LRA	Lithuanian Road Administration
LSVA	Leistungsabhängige Schwerverkehrsabgabe (Heavy Vehicle Charge, Switzerland)
LTA	Land Transport Authority (Singapore)
MPIC	Mobility Pricing Independent Commission, Vancouver (Canada)
MNO	Mobile Network Operator
MS	Member State (of the European Union)
NDS	Národná Diaľničná Spoločnosť (Slovak national motorway company)
NHAI	National Highways Authority of India
NSP	National Service Providers
NÚZS	Nemzeti Útdíjfizetési Szolgáltató, National Toll Service Provider (Hungary)

OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OEM	Original Equipment Manufacturer
OS	Open Service (for EGNOS and Galileo)
OSNMA	Open Service Navigation Message Authentication
OTA	Over-The-Air (for SW updates)
PC	Passenger Cars
PRS	Public Regulated Service (Galileo)
RIA	Road Infrastructure Agency
SAR	Search and Rescue Service
SEOPAN	Association of Construction Companies and Concessionaires of Infrastructures (Spain)
SoL	Safety of Life
TC	Toll Charger
TD	Toll Domain
TDO	Toll Declaration Operator
TfL	Transport for London (United Kingdom)
TSP	Toll Service Provider
ULEV	Ultra-Low Emission Vehicles
USA	United States of America
WiM	Weigh-in-Motion

EUSPA Mission Statement

The mission of the European Union Agency for the Space Programme (EUSPA) is defined by the EU Space Programme Regulation. EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the European Union.





Its goal is to:

- Provide long-term, state-of-the-art safe and secure Galileo and EGNOS positioning, navigation and timing services and cost-effective satellite communications services for GOVSATCOM, whilst ensuring service continuity and robustness;
- Communicate, promote, and develop the market for data, information and services offered by Galileo, EGNOS, Copernicus and GOVSATCOM;
- Provide space-based tools and services to enhance the safety of the Union and its Member States. In particular, to support PRS usage across the EU;
- Implement and monitor the security of the EU Space Programme and to assist in and be the reference for the use of the secured services, enhancing the security of the Union and its Member States;
- Contribute to fostering a competitive European industry for Galileo, EGNOS, and GOVSATCOM, reinforcing the autonomy, including technological autonomy, of the Union and its Member States;
- Contribute to maximising the socio-economic benefits of the EU Space Programme by fostering the development of a competitive and innovative downstream industry for Galileo, EGNOS, and Copernicus, leveraging also Horizon Europe, other EU funding mechanisms and innovative procurement mechanisms;
- Contribute to fostering the development of a wider European space ecosystem, with a particular focus on innovation, entrepreneurship and start-ups, and reinforcing know-how in Member States and Union regions.
- As of July 2023, EUSPA will take the responsibility for the Programme's Space Surveillance Tracking Front Desk operations service.

The European Union Agency for the Space Programme: linking space to user needs.

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