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National Automatic Toll Collection System for motorways, expressways and other roads

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ABSTRACT

The paper refers to some problems of European Electronic Tolling Service (EETS) implementation in Poland. Motor Transport Institute has developed the structure of the National Automatic Toll Collection System (NATCS). It consists of National Automatic Toll Collection Centre (NATCC), OBU and control subsystem. NATCS system is based on a combination of mobile communications using the GSM-GPRS standard technology, the satellite-based global positioning system (GPS) and 5, 8 GHz microwave technology. An innovative element of NATCS is the On-Board Unit (OBU), which automatically calculates the amount of charge due taking into account the vehicle category (admissible weight, number of axles), road distance and the emissions class (ecological aspect). The control subsystem distinguishes between automatic enforcement through control gates, enforcement by mobile teams, and patrol teams. This presented kind of system is the best toll solution for Poland because of unique capabilities.

KEYWORDS: European Electronic Toll Service(EETS), microwave technology

1. Introduction

There are two different types of European Electronic Tolling Service (EETS): Dedicated Short Range Communication (DSRC) and GPS/GSM based systems.

The first system (DSRC) is typically used as the primary method of charging where a charge is to be applied at one of a discrete number of specific points, such as a toll plaza (an area where tollbooths are located) or a location on the open highway. DSRC can be either closed (cordoned) or open. The closed system requires entrances and exits based on toll booth (a booth at a tollgate where the toll collector collects tolls). In an open toll system, toll stations are located along the facility. It is the collection of tolls on toll roads in three or more adjacent lanes without the use of lane dividing barriers or toll-booths. The major advantage to open system is that cars need not stop nor even slow down for payment.

All electronic tall systems, using microwave technology, all over the world have the same structure, which use vehicles equipped with transponders (electronic tags), toll and control gantries, in-road/roadside detection and classification sensors, computerized system (hardware and software) and wireless communication (5,8 GHz nearly all over the world, only 5,9 GHz in USA), as well as enforcement technologies.

The second system is based on an innovative combination of mobile telecommunications technology (GSM) and the satellite-based Global Positioning System (GPS). The main element of the automatic log-on system is the On-Board Unit (OBU). With the aid of GPS satellite signals and other positioning sensors, the OBU automatically determines how many kilometers have already been driven on the toll route, calculates the toll based on the vehicle and toll rate information that has been entered, and transmits this information to the computer centre for further processing. Software will be supported with electronic road maps and data of users registered as well as data charges of highways and expressways.

The electronic toll collection systems in the European Union member states are not interoperable due to differences in charging concepts, technology standards, classification and tariff structure, legal and institutional backgrounds. European Commission has taken bold steps to address that issue. The first one was Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004 on the interoperability of electronic road toll systems in the Community [1]. The second one was the decision to launch Europe's own Galileo system, which is predicted to improve upon both the accuracy and reliability of GPS. On June 26, 2004, the US and EU signed an agreement to coordinate Galileo and GPS.

According to the Directive, all new electronic toll collection systems brought into service on or after 1 January 2007 shall, for carrying out electronic toll transactions, use one or more of the following technologies: satellite positioning, mobile communications using the GSM-GPRS standard (reference GSM TS 03.60/23.060) and 5,8 GHz microwave technology.

The requirements of that directive will be implemented in Poland based on the Act from 7 of November 2008 and some other acts [4]. It stressed that toll collecting charge institutions should be able to carry out electronic toll transactions from 1 of July 2011.

2. The interoperable problems of EETS

Interoperability of road charging solutions is a long-term objective of the EC and as mentioned earlier, the directive 2004/52/EC of the European Parliament and Council on the interoperability of electronic road toll systems in the Community was adopted in April 2004. The new road charging service that is interoperable throughout Europe on the basis of one or more of the mentioned technologies is called the European Electronic Tolling Service (EETS).

Based on Directive 2004/52, the European Commission was seeking to establish an open framework for road charging (taxing or tolling) systems in Europe, which enables interoperability at the technical, procedural and contractual level and the EC initialized a process of projects and expert groups which would contribute to the formulation of, and consensus on, a definition of the European Electronic Tolling Service (EETS).

Within the framework of EETS, the three-year (2005 – 2008) Road Charging Interoperability (RCI) project, which is partially funded by the DG Energy and Transport of the European Commission, was developed by Consortium, currently consisting of 27 partners, including toll operators, suppliers, truck makers, representatives of both the DSRC and the GNSS[1] communities, and some specialist companies providing expertise on the relevant research issues [2].

In the RCI architecture, two charging principles for a tolled infrastructure are supported:

- DSRC-based tolled infrastructure: Charging data is generated in a real-time DSRC communication between the OBU and roadside microwave beacons.
- GNSS enabled tolled infrastructure: Data enabling GNSS tolling is generated in the OBU autonomously and the GNSS charge data is forwarded via the central system of the EETS. The Toll Charger receives the GNSS charge data trough a back-office interface and can use DSRC for enforcement and localization support. It is mentioned that within this concept, two or more tolled infrastructures could overlap. It is also noted that the DSRC-based tolled infrastructure could be deployed anywhere, including inside the domain of GNSS-enabled tolled infrastructure.

RCI Project was implemented and tested this framework in field trials at six sites as follows: Austria (ASFINAG), Germany (TOLL COLLECT), Italy (TELEPASS), France (TIS PL), Spain (VIA-T), Switzerland (LSVA).

The EC co-funds the Road Charging Interoperability (RCI) project to demonstrate and validate how RCI interoperable prototypes seamlessly, and without user intervention, adapt functional behavior when crossing the border according to the rules that apply for the German, Swiss, French, Spanish, Italian and Austrian tolling schemes. This contracted RCI mission was to be based on

[1] GNSS (Global Navigation Satellite System) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. GNSS-1 is the first generation system and the combination of GPS and GLONASS. GNSS-2 is the second generation of systems that independently provides a full civilian satellite navigation system, exemplified by the European Galileo positioning system.

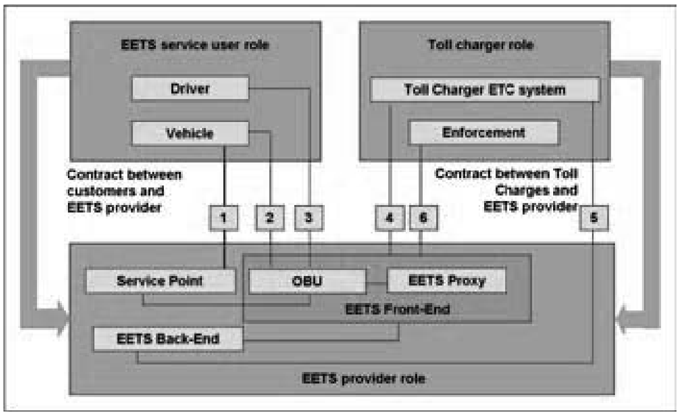

Fig.1.RCI Project architecture
Source: [2]

Fig.2.OBU - TRIPON EU OBU presented and accepted in 12 November 2008 in Brussels in RCI frame
Source: [5]

specifications that would be provided by the EC-coordinated expert groups (EFC) and the European Committee for Standardization (CEN). Although the EFC and CEN have delivered a specification for a number of important elements of the EETS, there has not been a clear definition or architecture for the EETS and several of the specifications needed are still missing. RCI therefore defined itself a high-level architecture for interoperability that is based upon work of the CEN and ISO standardization committees and the ASECAP tolling operators' and Member States' Stockholm Group role model (CESARE III).

The RCI architecture defines the technical detail of the interfaces for road charging systems that are interoperable in a manner that they correspond to the interfaces between the business entities that together operate the service: the Toll Charger, the Toll Service Provider and the Service User – fig.1.

The RCI architecture, presented to the EC in February 2007, represented a first European technical reference for DSRC- and GNSS-enabled road charging solutions that is accepted by the principal stakeholders (suppliers, toll operators and Toll Service Providers). Through demonstration, validation, consultation and awareness-increasing workshops, the RCI project intends to contribute to the further work on the EETS specification (and eventual standardization) and help to avoid delays in the future deployment of road charging systems or barriers to the introduction of interoperability.

The RCI architecture includes 6 interfaces. Interface 1 provides an in-vehicle access point for the servicing and maintenance of road charging OBU. Interface 2 defines how the OBU can be installed in a vehicle. Based on the high-level toll assurance needs, the operation of EETS requires a tamper-detecting fitting of the OBE in the vehicle. Furthermore, such an interface can clear the way to additional applications like VAS (Value Added Services) or allow for the easy use of already available (pre-/line fitted) vehicle components like antennas for GNSS/DSRC etc. Interface 3 provides access to the OBU for human interaction. Interface 4 enables sending toll charge data (also called use data) from the EETS Provider's Front-End to the Toll Charger's back-office. This interface can also be used for localization support via (augmentation) support beacons but only if the operation of location support- beacons is considered the responsibility of the Toll Chargers. Interface 5 enables the exchange of the specifications that define the specification of the Toll Chargers' tolled infrastructure (charge objects, charge events, tariff structure) and the expected behaviour of the EETS Providers systems when transmitting data (GNSS Charge Data format, frequency). Interface 6 enables the Toll Charger to carry out enforcement and compliance checking transactions with the OBU.

The final and ultimate task within the project was the demonstration phase (also called the Operational Testing): two trucks, each equipped with one interoperable OBU that seamlessly, and without user intervention, adapts functional behavior when crossing borders, according to the rules that apply to the Germany, Switzerland, France, Spain, Italy and Austria tolling schemes.

Two OBU`s: TRIPON EU (fig. 2) from FELA and second from Toll Collect (fig. 3) were tested within the of RCI project.

The final report stresses that RCI technical architecture should include the interfaces 4, 5 and 6, and sufficient to provide the levels of interoperability required for the EETS. RCI has been in close cooperation with CEN TC 278 WG1 which is working on finalizing the standards which will provide the definitions for the key interfaces 4, 5 and 6. These standards will be fully open and available.

RCI final report makes recommendations to [2]:

- continue and finalize the standardization of the interfaces (CEN) and the work on the contractual aspects,
- take into consideration the open issues (who defines charge objects' coordinates, who is responsible for augmentation systems and privacy),

Fig.3.OBU presented by Martin Biallowons from Satellic
Source: [6]

- define the technical EETS architecture and the interfaces, which are necessary for interoperability as elements in the EETS definition,
- determine the responsibility of the EETS Provider for the EETS Front-End (including the OBU) must be stated very clearly in the EETS architecture,
- initialize/coordinate activity envisaging the tools needed for performance monitoring that can help establishing trust, beyond EC marking,
- prepare for the EETS (industrial development, pilots, improvements),
- work with all stakeholders on a clear European roadmap of how progress will be made in the three years after the decision is finalized. This roadmap should make clear how the private sector can take its responsibility in the context of Member State action, European coordination and EC involvement.

Two mentioned OBU`s have the same structure and elements as follows: module structure of OBU in order to high flexible additional services, GPS receiver, position detect algorithm, GSM/GPRS module, chip card, DRSC module in order to spread services and interoperability.

Based on RCI program researches, Commission of the European Communities has prepared Decision on the definition of the European Electronic Toll Service (EETS) and its technical elements [3]. EETS sets out the necessary technical specifications and requirements for that purpose, and contractual rules relating to EETS provision. Decision lays down obligations on EETS Providers, Toll Chargers and EETS Users. EETS domain means a toll domain falling under the scope of Directive 2004/52/EC.

EETS Provider means a legal entity fulfilling the requirements and registered in a Member State where it is established, which grants access to EETS to an EETS User.

Toll Charger means a public or private organization which levies tolls for the circulation of vehicles in an EETS domain.

EETS User means a (natural or legal) person who subscribes a contract with an EETS Provider in order to have access to EETS.

On-board equipment means the complete set of hardware and software components required for providing EETS which is installed on board a vehicle in order to collect, store, process and remotely receive/transmit data.

Interoperability constituents means any elementary component, group of components, subassembly or complete assembly of equipment incorporated or intended to be incorporated into EETS upon which the interoperability of the service depends directly or indirectly, including both tangible objects and intangible objects such as software.

EETS Users do not interact directly with Toll Chargers as part of EETS. Interactions between EETS Users and EETS Providers (or their OBE) can be specific to each EETS Provider without compromising EETS interoperability.

Electronic interfaces between EETS Providers and Toll Chargers fall into two categories: Electronic interfaces at the roadside between the EETS Provider's OBE and the Toll Charger's fixed or mobile equipment, and electronic interfaces between the respective back office systems.

As a minimum, the following standardized back office interfaces must be implemented by all EETS Providers. Toll Chargers must implement each interface, but can choose only to support either the GNSS or DSRC charging process:

- Exchange of toll declaration data between EETS Providers and Toll Chargers, specifically: submission and validation of claims for toll payment based on DSRC charging transactions, submission and validation of GNSS toll declarations;
- Invoicing / settlement;
- Exchange of information to support exception handling: in the DSRC charging process, in the GNSS charging process;
- Exchange of EETS blacklists;
- Exchange of trust objects;
- Sending of Toll Context Data[2] from Toll Chargers to EETS Providers.

3. NATCS for Poland

Examples of Intelligent Transportation Systems applications may include: commercial vehicle operations, crash prevention and safety, electronic payment and pricing, emergency management, freeway management, incident management, information management, intermodal

[2] Toll Context Data means the information defined by the responsible Toll Charger necessary to establish the toll due for circulating a vehicle on a particular toll domain and conclude the toll transaction.

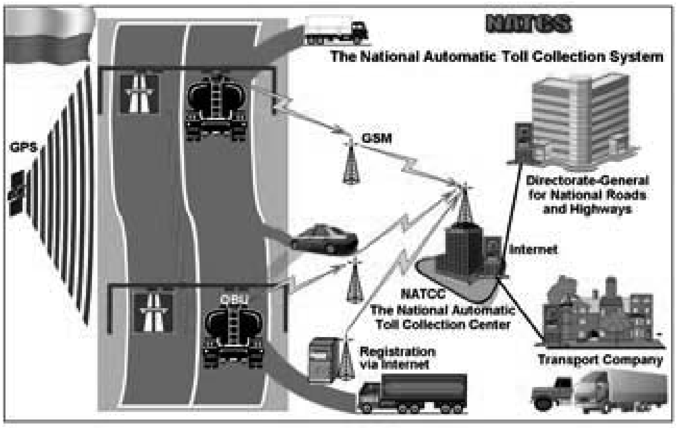

Fig.4. The structure of the National Automatic Toll Collection System (NATCS)

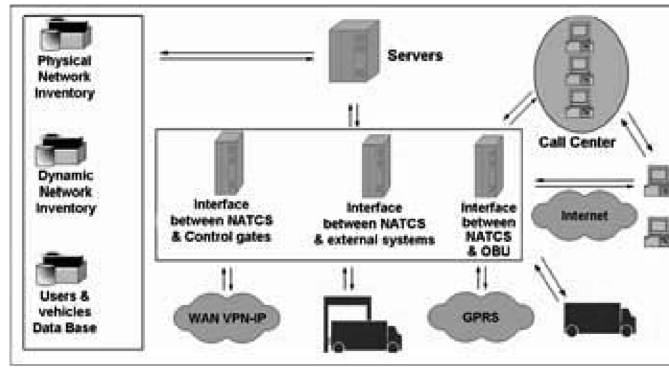

Fig.5. The structure of the National Automatic Toll Collection Centre (NATCC)

freight, road weather management, roadway operations and maintenance, transit management, traveller information.

The Motor Transport Institute has created the structure of The National Automatic Toll Collection System for Poland (NATCS). System will consist of The National Automatic Toll Collection Centre (NATCC), control gates, on-board units (OBU) and control subsystem – fig.4.

The National Automatic Toll Collection Center (NATCC) based on telematic system approved all functions performed for the National Automatic Toll Collection System (NATCS). The NATCC elements are as follows (fig. 5):

1. Redundancy servers.
2. Applications and system software.
3. Data bases.
4. Interfaces:
   - between NATCC and OBU,
   - between NATCC and control gates,
   - between NATCC and external systems (bank systems, Internet charge operators, Central Evidence Systems of Drivers and Vehicles).
5. User interface – www Internet service, Call Center, SMS gate, automatic telephone service.
6. Data transmission nets (WAN, LAN).

Data bases can be divided into following groups:

- Data of users, vehicles and charges.
- Physical Network Inventory.
- Dynamic Network Inventory.

Call Center should be used for the users' phone contact. Call Center workers should use special application – www Intranet service in order to verify ID of the person calling and for instance answer the questions and address claims.

The prototype of OBU will be manufactured by AutoGuard S.A. (fig. 6). It is a leading company on the Polish market that has produced telematics systems since 2000. Its experience is based on long-term cooperation with scientific and research institutes as well as on continuous analysis of new technologies that allow creating new telematics solutions.

OBU will be installed in vehicles windscreens and realized the following functions:

- Vehicles data storage.
- Digital map nodes and points storage.
- Toll charges calculation based on introduced data (admissible mass, No of axles, emission class, distance, tariff model).
- Analyze data coming from module and sensors (GPS, GSM, DSRC).
- Optical and sound signalization of OBU working parameters (for instance distance, fees).
- Safety data transmission to system and communication with control gates (stationary and mobile).
- Remote data actualization and parameters exchange.
- Data security based on cryptographic module.
- Additional DSRC module to spread services and interoperability.

The system is based on an innovative combination of mobile telecommunications technology (GSM) and GPS, the satellite-based Global Positioning System. The main element of the automatic log-on system is the On-Board

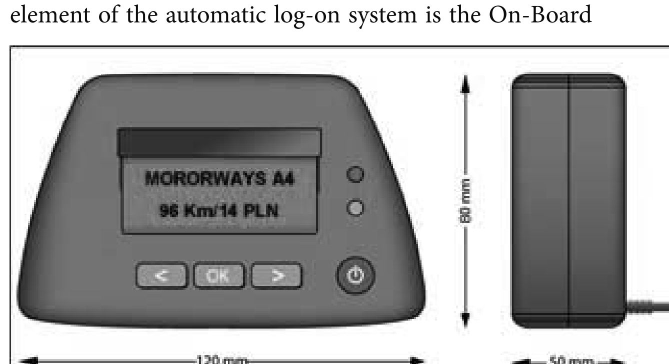

Fig.5. OBU prepared by AutoGuard S.A.

Unit (OBU). With the aid of GPS satellite signals and other positioning sensors, the OBU automatically determines how many kilometers have already been driven on the toll route, calculates the toll based on the vehicle and toll rate information that has been entered, and transmits this information to the NATCS computer centre for further processing.

Software will be supported with electronic road maps and data of users registered as well as data charges of highways and expressways.Charge counting will start after highway entrance gate and finished after highway exit gate. Data on vehicle position will be additionally approved by GPS system and delivered to NATCC by GSM net. The toll amount is based on the truck´s emission category and number of axles, as well as on the length of the toll route.

For truck drivers, automatic log-on requires the least amount of effort: they are not required to book the route themselves. All key data is already stored in the On-Board Unit. The prerequisite for participating in automatic log-on is registration of the transport company and the trucks with General Directorate-General for National Roads and Highways (DGNRH) and toll payment to DGNHR. After registration, the company receives a vehicle card for each truck. This card contains the most important vehicle information. With this vehicle card, the user can schedule an appointment with an authorized Toll Collect Service Partner to have an On-Board Unit installed.

The simplest way to pay the truck toll is to register the company and vehicles with DGNHR. A registered user can have an On-Board Unit installed and participate in automatic log-on and use all possible means paying the toll (credit account, credit card or fuel card, cash payment). Immediately after registering the company, it will receive a personal user number and a master PIN number for security. After vehicle registration, Toll Collect Service Partner will send the transport company a vehicle card for each truck, containing the most important information about the vehicle.

Toll enforcement and the punishment of violations are the responsibility of the Road Transport Inspection (RTI). Autoguard S.A. has provided RTI with the technology needed for an effective enforcement system so that RTI can enforce correct booking of the toll, thereby ensuring that all toll payers are treated equally. With the aid of this system, RTI can determine if a vehicle is has an obligation to pay toll and if it has met this obligation fully, partially, or not at all.

The control system distinguishes between automatic enforcement through control gates, enforcement by mobile teams and patrol teams. This combination guarantees comprehensive, continuous enforcement of the requirement to pay toll and allows the control system to be constantly adjusted to meet prevailing circumstances.

Automatic control subsystem consists of permanently installed enforcement control gates are used to ensure toll requirements are met without interrupting traffic flow. The automatic control gates come complete with (fig. 7):

- Laser scanner for vehicle detection,
- Laser scanner for No of vehicle axles,
- DSRC Module,
- Camera for registration of the number plate.

Laser scanners on the control gates scan the silhouettes of passing trucks to determine whether they are required to pay toll. A camera takes several digital photos of the truck's number plate. At the same time, DSRC communication is used to determine whether the vehicle is equipped with an On-Board unit. If so, the On-Board Unit transmits the current toll collection data to the control gate, where it is compared with the control data that has been recorded. If the vehicle does not have an On-Board Unit, its number plate is compared against a list of all Internet log-on data. This way, it is determined whether the driver has paid the correct toll based on the number of axles on the truck, its pollution class and the route under review. If the automatic review determines the toll has not been properly paid, the data is transmitted to enforcement headquarters for review. If the results of the automatic review are confirmed, the data is stored and provided to RTI to punish the offense. Once it has clearly been determined that the toll was paid, the data is deleted immediately.

RTI employees engage in portable (mobile) enforcement on parking lots in the vicinity of the control gates. Mobile inspections are carried out by RTI officers at selected parking lots near the control gates. The control mobile teams receive wireless data on vehicles that may have not properly paid the toll. This occurs seconds after the truck passes under the control gates. The team then pulls the truck over for a detailed inspection.

RTI will have approximately 100 control vehicles throughout Poland to provide patrol toll enforcement. The

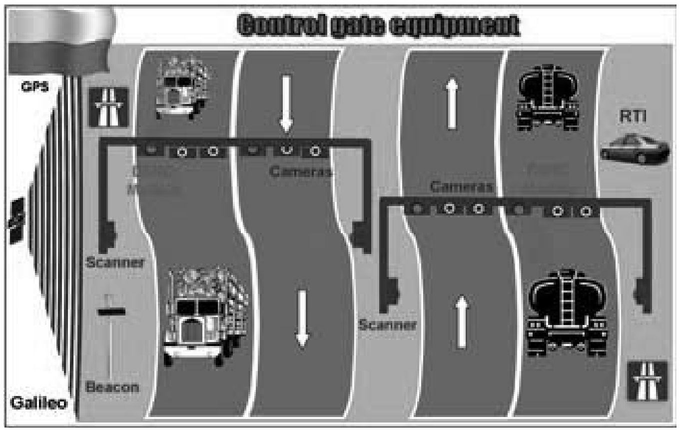

Fig.3.Control gate with other electronic equipment

enforcement patrol teams use infrared technology to determine whether passing trucks are logged onto the automatic system and if their vehicle information has been properly entered. The teams can check manual log-on data directly with Toll Collect headquarters by using a PC with mobile telecommunications equipment. If RTI determines a toll has not been properly paid, it can immediately pull the truck over.

Where incontrovertible evidence of non-payment or incomplete payment of the toll is established, the amount of toll due for the travelled route will be retrospectively charged, and the defaulting user is also liable for payment of a fine. Where the actual route cannot be determined, a retrospective charge will be made for a nominal distance of 300 km. During the enforcement check, the required input data, including vehicle registration or toll-rate class, will be recorded and summary proceedings will be instituted by RTI against the defaulter.

4. Conclusions

For many years, microwave-based digital short range communication (DSRC) systems have been preferred, due to their simplicity of operation, potential for supporting additional services for vehicle users and, most importantly, because they are easy for users to understand. These systems need road-side equipment, typically mounted on a gantry, with electronic tags in the vehicles which may be read-only, read–write or smartcard-based. The key limiting factor seems to be the processing speed of the smartcard – each charging point has two gantries – one to start communications with the vehicle and a second (further down the road) to complete the transaction and perform enforcement measures, if necessary.

A new class of ETC systems is based on a combination of mobile communications technology (GSM) and the satellite-based global positioning system (GPS). An innovative element of the automatic log-on system is the On-Board Unit (OBU), which automatically calculates the amount of charge due and takes into account the emissions class (ecological aspect) and the number of vehicle axles in calculating this charge. The first GPS based system advantage is an absence of the need for new road infrastructure (gantries), while the operators can keep using the existing infrastructure. System works without toll booths, extra lanes, speed restrictions or complex structures along toll roads. The second one is much greater flexibility in defining or changing payment by simply redefining the "virtual" toll areas. It means the ability to adapt easily and quickly to changes in charge parameters (road classes, vehicle types, emission levels, times slots etc). The third is the systems ability to support other value-added services on the same technology platform. These services might include fleet and vehicle engine management systems, emergency response services, pay-as-you-drive insurance services and navigation capabilities.

With regard to future expansion and development, the satellite-based toll collection system will be a better solution, especially with regard to flexibility when it comes to extending toll collection to every road category, every category of vehicle and, what's more, in terms of cost efficiency in implementation and operation.

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