TECHNICAL REPORT

ISO/TR 21190

First edition
2018-12

Electronic fee collection — Investigation of charging policies and technologies for future standardization

Perception du télépéage — Examen sur les politiques et technologies de tarification pour la future normalisation

Reference number
ISO/TR 21190:2018(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

An electronic fee collection (EFC) system, introduced in many countries around the world, is used for collecting road construction funds or repaying loans for construction of toll roads. Toll roads have enabled large-capacity and high-speed movement of people and goods, and contributed greatly to social and economic development in the introduced countries. As an internalization of external costs for road pavement damage by heavy goods vehicles (HGV), HGV charging has been introduced in member countries widely under the support of the European Commission. EFC is also effectively used for mitigating congestion in urban area as a traffic management measure.

The EFC technology that realizes these charging policies is classified as dedicated short-range communication (DSRC)-based system and autonomous system, and EFC systems developed based on these major standards have been introduced in countries all over the world. In addition to the above charging policies and technologies, several important new charging policies realized by new technologies are planned and trial operations are being carried out.

In Tokyo metropolitan area, road users can use smart route selection from among several optional routes according to their judgment of whether a priority given to reduction of travel time or priority to charge amount. As another new policy, several pilot operations of road usage charging have been introduced in the United States to raise funds for road maintenance as an alternative for the current fuel tax.

These new charging policies can make road users more convenient or road maintenance sustainable in accordance with evolution of technologies. As an another example of new charging policy, there is the managed lane such as high occupancy tolling/high occupancy vehicle (HOT/HOV) lane which is already operated in the United States, where it can be used for free with a certain number of crew members, but paying the fee with existing charging technology enable road users to use it even under a certain number of crew members.

In this document, the relationship between charging policies and EFC technologies are investigated in order to propose future standardization themes.

Table 1 shows the major charging systems realized from charge policy and EFC technology.

Table 1 — Major charging systems realized from charging policy and EFC technology

Charging policies EFC technologies	Conventional charging policy	New charging policy
Existing technology	— Toll road charging (ETC) — HGV charging — Congestion charging	— Managed lane (HOT/HOV)
Emerging technology	(Applicable to the above charging systems)	— Smart route selection — Road usage charging (RUC)

Electronic fee collection — Investigation of charging policies and technologies for future standardization

1 Scope

This document investigates the stemming from requirements of charging policies and corresponding charging technologies in order to propose future standardization theme candidates.

This document reports the findings of the investigation of charging policies and technologies in order to:

— Classify the conventional charging policies and the new charging policies and their functional requirements.

— Classify the existing technologies and the emerging technologies to be used for EFC services or other intelligent transport system (ITS) services.

— Conduct a gap analysis between the needs of the new charging policies and the existing standardized technologies for EFC.

— Recommend development of emerging standards or amendments for existing EFC standards according to the results of the gap analysis.

Figure 1 shows the process for preparing this document and the scope.

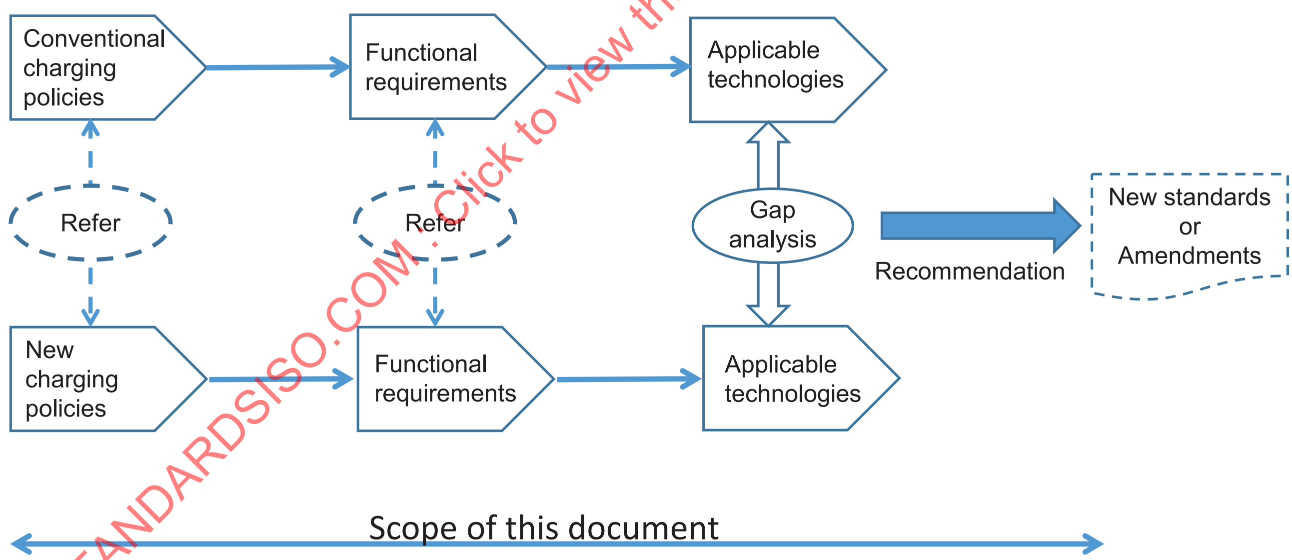

Figure 1 — Scope and process flow of this document

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
level of service
LOS
rating of the quality of transportation facilities and services from the user's perspective, which refers to the speed, convenience and comfort to evaluate problems and potential solutions

3.2
open payment
system that uses open interfaces for validating payment

3.3
passive RFID
RFID system, where the OBU is a passive-backscattering device

3.4
passive ultra high frequency RFID
passive UHF RFID
passive RFID, operating in the 860 MHz to 960 MHz frequency range

Note 1 to entry: Note 1 to entry: Passive UHF RFID as defined in ISO/IEC 18000-63 unless otherwise specifically stated.

3.5
transport performance requirement
needed level of service related to a set of operational goals and performance measures, e.g. speed, travel time, freedom to manoeuvre, traffic interruptions, comfort or convenience

3.6
radio frequency identification
RFID
wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from an OBU attached to an object, for the purposes of automatic identification and tracking

Note 1 to entry: Adapted from ISO/TS 16791:2014, 3.1.24.

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

A-GNSS Authenticated GNSS

AES Advanced Encryption Standard

AET All Electronic Tolling

ANPR Automatic Number Plate Recognition

ASTM American Society for Testing and Materials

CCC Compliance check communication for autonomous systems (ISO 12813)

C-ITS Cooperative – ITS

CN Cellular Network

CN-3G	Cellular Network 3rd Generation
CN-4G	Cellular Network 4th Generation
CN-5G	Cellular Network 5th Generation
COST	European Cooperation in Science and Technology
DOT	Department of Transportation
DSRC	Dedicated Short-Range Communication (ISO 14906)
EPC	Electronic Product Code
FETC	Far Eastern Electronic toll Collection
GNSS	Global Navigation Satellite System
HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
HOT	High Occupancy Tolling
HOV	High Occupancy Vehicle
IAG	Inter-Agency Group
IMT	International Mobile Telecommunication
ITU	International Telecommunication Union
KEC	Korean Expressway Coporation
LAC	Localisation augmentation communication (ISO 13141)
LEZ	Low Emission Zone
LOS	Level Of Services
MLIT	Ministry of Land Infrastructure and Transport
OBD	On-Board Diagnostics
PCU	Passenger Car Unit equivalent
RFID	Radio Frequency Identification
RUC	Road Usage Charging
TANFB	Taiwan Area National Freeway Bureau
UHF	Ultra High Frequency
WAVE	Wireless Access in Vehicular Environments
WIM	Weigh-In-Motion

5 Charging policies

5.1 General description

Road networks are the most important infrastructure of land transportation to support social economic activities such as, among others, freight transportation, human mobility and emergency transportation activities in disaster relief. While road charging has been applied as a means of raising funds for the construction, the maintenance and the operation for those road networks, it has been also applied to reduce congestion in urban areas as a means of traffic management.

On the other hand, vehicles using the road networks generate external costs such as air pollution caused by running exhaust gas and deterioration of the living environment due to noise. For this reason, policies are being studied to make these external costs associated with road transport be borne by those who cause these factors. For charging to HGV especially in Europe, the policy was enacted by European Directive (2011/76/EU) to allow the charge amount to include external costs in addition to road network construction and maintenance fees.

The legal systems concerning road charging have already been enacted in each country where they are introduced to realize charging policies, and examples of legislation in major regions and countries are shown in Annex D.

It has to be noted that, although in general a policy is technology agnostic, in some cases a policy addresses one specific technology for reasons that are not of an engineering nature, as for example when technology is mandated due to economic reasons. This is reflected in some cases later on.

5.2 Conventional charging policies

5.2.1 Financial sources for road construction

Construction of road networks requires a great deal of funds, therefore road operators construct them by borrowing funds from financial institutions that should be repaid by collecting tolls from the road users during a predetermined fixed period of time. Even if the loan repayment is completed, the toll charging will be continued in order to pay for road maintenance and facility management in some cases.

The so called “shadow tolling”, i.e. using general tax revenues to repay for road construction and maintenance with no explicit road toll collected road users, is outside the scope of this document.

5.2.2 Financial sources for road maintenance

HGVs registered in other countries drive on the highways or the general roads of the home country, so that the road damage caused by these HGVs has caused serious problems in European countries. These situations made it possible to charge even for the vehicle of other nationalities that carry out the international road transport by European Directive (1999/62/EC).

Based on this European Directive, HGV charging aiming for environmental protection started in Switzerland in 2001. Since then, HGV charging operations started in Austria in 2004, in Germany in 2005, and in the Czech Republic in 2007. Fee revenues in these countries using mainly the financial resources for road maintenance, have been also been used for some rail network maintenance and waterway maintenance.

5.2.3 Reduction for congestion in urban area

Economic losses caused by traffic congestion in urban areas is a serious problem, therefore it has been shown theoretically that the traffic volume can be reduced by introducing charging in the selected areas. The theory has been demonstrated in an actual operation in Singapore since 1998, followed by London in 2003, and Stockholm in 2006, where environmental improvements were reported along with reduction in traffic volume. The fee revenues are used for both road construction and improvement of public transportation.

In Singapore, traffic volume has been controlled by varying the charging rates to keep traveling speed within the pre-defined range based on the measurement of the traffic situation every three months.

5.2.4 Internalizing external costs

Internalisation of external costs is based on the principle that the users of the road network pay the costs that each road user imposes on the society and the other road users. These costs are related to accidents, congestion, noise, environment and road wear. In a theoretically correct road use charging system, any road user should pay the costs imposed on the society. This is difficult to implement completely and some simplified variants have been implemented for many years.

The above mentioned congestion charging and some part of HGV charging may be included in this item theoretically, but this clause describes from the viewpoint of environmental protection. Low emission zones (LEZ) focus on the environment and the main objective of LEZ is to reduce the pollution caused by vehicles using fossil energy by means of EFC where the tariffs reflect the vehicle pollution characteristics.

LEZ has been introduced in many cities in Europe and its effects have been confirmed. Taking into account the impact on citizens' health from the traffic noise, comprehensive countermeasures are considered by European Directive (2002/49/EC) such as Q-Zone in the city centres where only electric vehicles will be allowed to circulate.

The environmental impact caused in Switzerland by truck traffic between Germany and Italy was determined as a serious problem, therefore a toll schema for HGV weighing 3,5 t or more was introduced in 2001. The charge revenue was used to the construction funds for a new tunnel that enables goods transportation to be diverted from trucks to railways.

5.2.5 Summary of conventional charging policies

The charging policies discussed above are categorized based on their objectives as shown in Table 2.

Table 2 — Conventional charging policies

Charging policy	Method
1. Financial source for road construction	To charge for all vehicles with tolls depending on the impact of vehicles on the road.
2. Financial source for road maintenance	To raise funds for road maintenance or reconstruction by charging for HGV in use.
3. Reduction for congestion in urban areas	To charge for all vehicles circulating in the area.
4. Internalizing external costs	To charge for all vehicles with tolls depending on the impact of vehicles on the environment.

5.3 New charging policies

5.3.1 Financial source for road construction with low cost devices

In developing countries, the need for repayment of road construction costs by EFC is hindered by the cost of EFC equipment, especially the OBE. A new charging policy is to charge all vehicles using low-cost, high-performance devices such as passive (UHF) RFID, which have been developing in recent years.

5.3.2 Financial source for road maintenance alternative to fuel tax

While many countries have been reliant on the fuel tax to finance road maintenance, fuel tax revenues are in a downward trend due to the recent spread of high fuel efficiency cars and electric vehicles. In the USA road usage charging to substitute the fuel tax has been studied for the past 10 years, and the field operation test of road usage charging to use odometer and other methods has been carried out since July 2016. A new policy is to replace the fuel tax by road usage charging based on the travelled distance.

5.3.3 Provision of appropriate route or lane

In Tokyo metropolitan area, while construction of a road network composed of plural radial roads and plural ring roads has been progressed, a dynamic charging scheme depending on the degree of congestion has been studied for selecting an appropriate route to destination for avoiding traffic jams in the central Tokyo area. As for measurement of traffic flow, probe data from the global navigation satellite system (GNSS) receiver equipped in-vehicle unit is expected to carry out vehicle tracking in addition to the conventional vehicle detectors.

In the United States as a return of charging to a specific lane of the inter-urban roads, a minimum traveling speed and travelling time to destination are guaranteed to some extent. For this reason, charging rate is determined based on the traffic volume measured by every predetermined time interval (for example, 5 min). This specific lane is called a managed lane or HOT lane and also serves as an HOV lane where cars with a certain number or more of occupants are allowed to pass through free of charge. A new policy is thus to manage traffic flows by modulating tolls.

5.3.4 Integration of C-ITS technology with EFC

C-ITS stations have been introduced in vehicles for safety applications, but could also be used for tolling applications. While this has not be done so far, in the near future a new policy that requires using the same communication media for all vehicle applications including tolling can be expected.

5.3.5 Fair charging rates

As vehicle caused damage to road pavement is said to be proportional to the fourth or fifth power of the axle load, the charging rates adopted for toll roads in the world are generally proportional to the number of vehicle axles. While it could be acceptable for full loaded vehicles to be charged based on the number of axles, a fairness problem arises in the case of empty vehicles which are charged at the same charge rate as when they are full loaded.

A new policy that regulates the toll rate based on the actual gross vehicle weight would overcome this problem of fairness.

5.3.6 Summary of new charging policies

New charging policies are categorized based on their objectives, as shown in Table 3.

Table 3 — New charging policies

Charging policy	Method
1. Financial source for road construction with low cost devices	To repay the road construction and the maintenance costs by charging all vehicles with low cost devices.
2. Financial source for road maintenance alternative to fuel tax	To charge for all vehicles using public roads based on vehicle miles travelled as an alternative to the fuel tax.
3. Provision of appropriate route or lane	To induce the appropriate route in metropolitan areas or appropriate lane in inter-urban roads by varying toll tariffs based on the road traffic and notifying the road user.
4. Integration of C-ITS technology with EFC	To bring all in-vehicle applications including road charging, to use the same hardware and communication media.
5. Fair charging rates	To define charge rate based on the gross vehicle weight.

5.4 Integrated charging policies

5.4.1 General

The same charging policy can be achieved by different charging methods, and the same charging methods could achieve different charging policies. Table 4 at the end of this clause shows an integration of the conventional charging policies and the new charging policies. In the following clauses the charging policies and how they can be achieved by different charging methods are described.

5.4.2 Financial source for road construction and maintenance

There are three different policies to reach this objective. Each of them is based on raising funds by charging every vehicle, however they may lead to different technological choices. The first policy is to use conventional equipment (OBE on board of vehicles), the second one dictates the use of low cost equipment such as to impose specific low cost technologies such as passive RFID, while the last policy imposes using the same hardware and communication equipment for all ITS applications, including tolling. A further differentiation lies in applying a toll to all roads to ensure their maintenance, or to special roads that offer a higher level of service.

5.4.3 Traffic management by charging

There are three kinds of policies to reach this policy objective. The first one is to apply charging to reduce congestion in urban roads. The second one is to differentiate routes in a metropolitan area by dynamic charging. The last one is to differentiate lanes in inter-urban roads by dynamic charging.

5.4.4 Internalizing external costs

A full internalisation of the external costs is not feasible today but could become feasible in the future when data collection and data management enable it. In the meantime, several policies are implemented to achieve internalisation of parts of all the parameters covering the external costs such as road wear, pollution and congestion.

For implementing such policies a coordinated usage of charging and enforcement technologies is necessary, e.g. based on passive UHF RFID and ANPR technologies.

5.4.5 Fair charging rates

From a road maintenance viewpoint, a charging policy of toll-by-weight is the best solution in that charging rate is dependent on a degree of road damage caused by the weight of vehicles. However, a technology to effectively adopt such a policy has not yet been deployed widely.

On the other hand in urban congestion charging, it has to be noted that a fair charging rate should be proportional to the vehicle occupancy to the road. This means that fairness can be reached through different policies and different technologies according to the type of charging objectives.

5.4.6 Summary of integrated charging policies

Table 4 integrates all policies described so far in terms of the policy objectives that have been described.

Table 4 — Integrated charging policies (new charging policies indicated by shaded cells)

Charging policy	Method
1. Financial source for road construction and/or maintenance	To charge all vehicles with conventional equipment for using toll roads.
	To charge all vehicles with low cost equipment for using toll roads.
	To charge all vehicles using available C-ITS equipment for using toll roads.
	To charge only HGVs for using the roads (HGV charging).
	To charge all vehicles based on the actual distance travelled for using the roads (Road usage charging).
2. Traffic management by charging	To charge all vehicles in urban roads to mitigate congestion (Congestion charging).
	Induce the route selection in metropolitan areas by dynamic charging (Smart route selection).
	Induce lane selection in inter-urban roads by dynamic charging (Managed lane).
3. Internalizing external costs	To charge all vehicles based on the accidents, delays, noise, pollution and road wear each vehicle imposes on society and other vehicles.
4. Fair charge rate	To define charge rate based on the gross vehicle weight.

6 Functional requirements

6.1 EFC function

6.1.1 EFC functional model

EFC functions to realize each charging policy are composed of charging, payment, information provision and enforcement. Communications including DSRC, CN and other ground communications are not a function of EFC but media to combine each function that is performed by front-end equipment such as RSE or OBE, or back-end equipment so as to achieve functionality of EFC. Securities are applied for protection of information being communicated through media.

As a counter function to charging, payment is an essential function of EFC in which users have to pay a claimed charge amount determined by charging. Two payment modes are already established and categorized as on-board account and central account where necessary themes have already been standardized. Though there is open payment as a new policy for a payment system, they should be out of scope because they have already been studied for standardization in other work items.

Figure 2 shows an image of EFC functions and their relations.

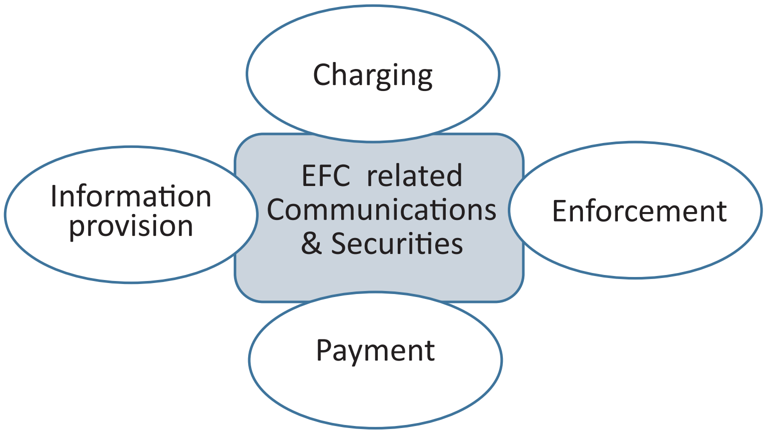

Figure 2 — EFC functional model

6.1.2 Charging

Charging is the most important function of EFC that determines an amount road users are charged. The main factor of charging is the distance driven and the distance unit price, and a charge amount is then multiplied by these two items. The distance unit price is also called tariff information, and is determined by a combination of vehicle class, user class, time class, location class, etc., based on the charging policy.

6.1.2.1 Distance driven

There are two methods to measure distance driven, one is a direct measurement performed by a vehicle sensor, and the other is an indirect measurement performed by cooperating GNSS positioning data and the road map database. Other methods, e.g. route ticket or self-declaration, are out of scope of this document.

There are several methods to measure distance driven that are required for high precision because they directly affect the charge amount to measure distance driven with:

— a vehicle sensor such as odometer directly;

— road segment detection cooperated by GNSS and road map;

— road segment detection performed by DSRC;

— road length detection performed by two point–based DSRC.

6.1.2.2 Tariff information

The next important item for determining the charge amount is tariff information composed of vehicle classes, user classes, time classes, location classes, etc., with different priorities for each item according to the charging policy. Figure 3 shows a structure of the tariff information defined in ISO 17575-3.

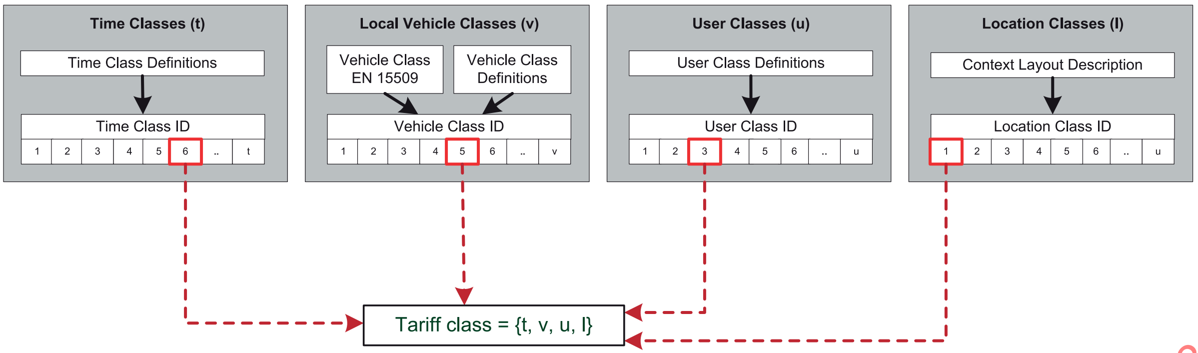

Figure 3 — Tariff class (Source: ISO 17575-3)[41]

6.1.2.2.1 Vehicle class

The basic idea of the vehicle class is determined by the charging policy based on the degree of influence on road surface damage, the degree of traffic congestion, and the degree of influence on the environment.

(1) Example in HGV charging

The charge rates of HGV charging in Germany are defined by the combination of emission class proportional to the degree of influence to the environment, and number of axles proportional to the degree of influence to the road damage (refer to B.1.1).

(2) Example in urban congestion charging

The charge rate of urban congestion charging in Singapore is defined by the Passenger Car Unit (PCU) equivalent that is nearly proportional to a projected area on the road.

- Cars, taxis and light goods vehicles are 1 PCU.
- Motorcycles are 0,5 PCU.
- Heavy goods vehicles and small buses are 1,5 PCU.
- Very heavy goods vehicles and large buses are 2 PCU.

6.1.2.2.2 User class

The user class is applied on, e.g. HOV lanes in the USA where charging rates are different in accordance with the number of passengers. Another example is in Japan, where the charge rate for a passenger car driven by physically disabled person is discounted.

6.1.2.2.3 Time class

In urban congestion charging the charge rate varies according to the traffic condition. The charge rate in Singapore is adjusted by a quarterly review of traffic speeds on the roads to keep optimal speed ranges of 20 km/h to 30 km/h on arterial roads and 45 km/h to 65 km/h on expressways.

6.1.2.2.4 Location class

Location class depends on the charging policy, in case of urban congestion charging, the charging rate is low or free of charge in places where the degree of congestion is light or non-existent, and high in places where the degree of congestion is heavy.

Also in the toll roads, there are cases where the charging rate is set higher in sections containing tunnels in mountainous areas or in sections containing bridges in coastal areas than in flat areas.

6.1.2.2.5 Traffic conditions

In the case of urban congestion charging and route selection the charge rate varies in accordance with the traffic conditions, therefore it is important to predict or measure traffic conditions. On the other hand in the case of toll roads and HGV charging, the charge rate does not depend on traffic conditions.

6.1.3 Enforcement

Enforcement is as important as charging in EFC. If the enforcement function does not work well there is a decrease in system reliability by illegal traffic by payment avoidance or overloaded vehicles. Therefore, the enforcement is required to have the same certainty as charging.

6.1.3.1 Payment avoidance

Though automatic gates or barriers have been used effectively to cope with the problem of vehicles that pass a toll gate without paying in single-lane EFC, this approach has some negative effects such as a decrease in throughput due to lower running speed and accidents caused by collisions at the gate bar. An alternative method is to use enforcement cameras to capture the license plate of an illegally passing vehicle, and it seems to be the only method for enforcing illegally passing vehicles in multi-lane free-flow EFC.

Vehicles passing illegally are determined under the condition that the charging process via DSRC is not completed properly, which triggers the enforcement camera to take an image of the vehicle's license plate. As an alternative, a method of recognizing the number plates of all passing vehicles and storing these in a database has been put to practical use. In this method, the image of the license plate of a compliant vehicle is deleted from the database, and the image of the license plate of a non-compliant vehicle is not deleted from the database, so that the non-compliant vehicle can be identified.

6.1.3.2 Overloaded vehicle

Enforcement against overloaded vehicles is commonly conducted by law enforcement agencies such as the police, not the road operators. However, the same technology as for preventing non-payment cases is applicable to enforce overloaded vehicles.

6.1.4 Information provision

Notifying tariff information and the charge amount to a user in EFC are similar to any business transaction or normal shopping. However, the importance of the notification is different by the charging policies. In the case of urban congestion charging and route selection, the charging rate is different depending on the location and time zone, therefore it is essential to notify the users promptly of the latest tariff information.

On the other hand in the case of toll roads and HGV charging where the charging rate is fixed, it is sufficient to display the charging rate on roadside panels in most cases.

6.1.4.1 Tariff information

In many cases, tariff information is posted on the web site of toll service providers in order to help users to be informed prior to the use of toll roads.

In case of managed lanes such as HOT/HOV, the notification of the charge rate is required for users to decide on route selection or lane selection on the basis of this information that varies in correspondence to the time zone and congestion degree.

However, in the case of the urban congestion charging or the route selection, it is necessary for users to know the tariff information prior to the time of use, therefore HMI function of the vehicle-mounted equipment and roadside variable display board is necessary.

6.1.4.2 Charge amount

How to notify the charging amount to the user varies depending on the charging policies. In a case of a small scale toll road, it is possible to notify the charging amount by a sign at the roadside because the distance and the unit price to the destination has been predetermined. However in a case of the road usage charging, where users do not know the distance driven it is necessary to notify the charging amount to the users via HMI of the OBE or similar equipment.

Notification of charge amount to the users is essential because it is actually paid at the time of road usage or paid later. In the case of DSRC-based EFC, it is possible to notify the user of the charge amount via HMI of OBE in real time. In case of the thick client of autonomous systems, it is also possible to notify the user of the charge amount via HMI of OBE in real time. However, in the case of the thin client there is a time delay for users to get the charge amount because of data transfer time delay from the central system that determines charge amount.

6.1.4.3 Level of service

A specific agreed level of service is referred to as transport performance requirements and defined as needed level of service related to a set of operational goals and performance measures, e.g. speed, travel time, freedom to manoeuvre, traffic interruptions, comfort or convenience. It is important to provide a driver with information about the required time to the destination or guaranteed driving speed in order to select a toll lane or optimum driving route.

In particular, this information is essential in the express lane at the inter-urban roads where the user can make a decision whether to change into the express lane or stay in the normal lane on the basis of this information. It is also necessary for other route selection situations.

6.1.5 Payment

There are two types of payment method, one is the central account and the other is the on-board account. In the case of the central account, the charging amount is determined by the central system and transferred to OBE via the communication network with the associated information.

In the case of the on-board account a charging amount is determined by OBE itself and settled by the account in OBE and IC card carrying the related purse.

6.2 Relation between charging policies and EFC functions

The necessary functions of each policy objective and their degree of importance are shown in Table 5, among which required degree of importance for the distance driven and the vehicle class, and the enforcement against a payment avoidance vehicle are high.

Notable requirements for traffic management are a high degree of importance for the tariff information, LOS, and the information provisions of charged amount in addition to user class and traffic conditions.

The definition of degrees of importance are as follows.

a) Most important items for implementing the charging policy, so that for example a high measurement accuracy for the distance driven or the high vehicle detection rate is required.

b) Though it is important items for implementing the charging policy, measurement accuracy or detection rate are not required as much as a).

c) Necessary items for implementing the charging policy.

Table 5 — Degree of importance for EFC functions

EFC functions / Policy objectives	Charging						Enforcement		Information provision		
	Distance driven	Tariff information					Payment avoidance	Over loaded	Tariff or other info.	LOS	Charge amount
		Vehicle class	User class	Time & Day	Location	Traffic condition					
1.Financial source for road construction and/or maintenance	A	A			C		A	C	B		B
2.Traffic management by charging	A	A	A	B	B	A	A	C	A	A	A
3.Internalizing external costs	A	A			A		A	B	B		B
4.Fair charge rate		A									

[Note-1] blank cells mean n/a

6.3 EFC functional requirements

Each EFC functional component has different requirements for degree of importance depending on charging policies as mentioned in 6.2. With consideration of these degrees of importance, general requirements in view of degree of importance for each functional component are summarized hereinafter.

6.3.1 Charging

6.3.1.1 Distance driven

Distance driven should be measured precisely as possible, because distance driven affects the charging amount directly.

6.3.1.2 Tariff information

The tariff information is composed of the following items, and in the case of distance based charging, the distance unit price of the charge amount is determined based on these.

a) Vehicle class

The vehicle class is classified according to the charging policy based on the size of the vehicle and number of axles and the emission class of engines to be used, and is usually registered in advance in the OBE. Since the vehicle class directly affects the charge amount, the compliance check for the vehicle class is performed by the roadside sensor from the viewpoint of fraud prevention.

b) User class

In the case of the HOV lane, a user class defined by number of occupants affects charging amount, therefore the number of occupants should be checked correctly. At this moment a checking method is performed by visual confirmation by administrators only and has not been established technically.

c) Time class

In the case of urban congestion charging, charge rate changes from time to time with reflecting degree of congestion, therefore clock data should be maintained correctly in the OBE.

d) Location class

In the case of road usage charging, charging is not applied to a private road or the out of state roads, therefore location data should be identified as chargeable roads or not correctly.

e) Traffic conditions

In the case of EFC assist traffic management, the charging rate is changed according to traffic conditions, therefore traffic conditions should be detected correctly and timely.

6.3.2 Enforcement

6.3.2.1 Payment avoidance

Payment avoidance is a serious non-compliance activity for every charging service, therefore payment avoidance vehicles should be detected and identified with certainty.

6.3.2.2 Overload

Overload is an illegal activity for every road, therefore an overloaded vehicle should be detected and identified with certainty.

6.3.3 Information provision

6.3.3.1 Tariff information

In the case of charging assist traffic management, tariff information is important for users to decide whether to select a route or change a lane, therefore the latest tariff information should be provided to users correctly.

6.3.3.2 Charge amount

In many charging services, the charge amount should be notified to users properly and timely.

6.3.3.3 Level of service

In the case of charging assist traffic management or urban congestion charging, level of service (LOS) information is important for users to decide whether to select a route or change a lane, therefore the latest LOS information should be provided to users correctly.

6.3.4 Summary of EFC functional requirements

The requirements for each component of the EFC functions are shown in Table 6.

Table 6 — EFC functional requirements

EFC functions	Components		Requirements
Charging	Distance driven		Distance driven should be measured precisely as possible, because distance driven affects charging amount directly.
	Tariff information	Vehicle class	Vehicle class should be measured correctly or precisely as possible, because vehicle class affects charging amount directly.
		User class	The number of passengers should be checked correctly.
		Time class	Clock data should be maintained correctly in OBE.
		Location class	Location data should be identified as chargeable roads or not correctly.
		Traffic condition	Traffic conditions should be detected correctly and in a timely manner.
Enforcement	Payment avoidance		Payment avoidance vehicle should be detected and identified certainly.
	Overloaded		Overloaded vehicle should be detected and identified clearly.
Information provision	Tariff information		The latest tariff information should be provided to users properly.
	LOS		The latest LOS information should be provided to users properly.
	Charge amount		Charge amount should be notified to users properly and in a timely manner.

7 Technology for requirements

7.1 General

In this clause, the technologies or devices to realize the EFC functional requirements in the previous clause are described.

7.2 Charging

7.2.1 Distance driven

There are three technical methods to measure distance driven for charging.

7.2.1.1 Measurement with vehicle sensors directly

Distance driven data is collected from the vehicle sensor directly, e.g. odometer or tachograph.

7.2.1.2 Measurement with detecting road segments or entry/exit indirectly

There are two methods for measuring the distance driven indirectly.

— Distance driven by detecting road segments or entry/exit cooperated by GNSS positioning and map matching where road length of particular segment or pairing entry and exit should be predetermined.

— Instead of GNSS positioning and map matching, DSRC is also applicable to detect road segments or entry/exit where DSRC transceivers are installed.

7.2.1.3 Measurement with detecting road entry/exit and route

In case that there are multiple routes to the destination, distance driven is determined by a combination of entry, route, and exit information where DSRC transceivers are installed.

7.2.2 Vehicle class

There are four technical methods to detect vehicle class.

7.2.2.1 Measurement of number of axles

There are two methods for measuring the number of axles.

— using a treadle or inductive loop installed in the roads way;

— using a laser or image sensor installed on the overhead gantries.

7.2.2.2 Measurement of vehicle weight

To measure vehicle axle weight and/or gross weight with weigh-in-motion technology (WIM).

7.2.2.3 Measurement of vehicle size

To measure vehicle length, width, and height with overhead sensor.

7.2.2.4 Detection of emission class

To read out the vehicle's emission class, as registered in the OBE.

7.2.3 Time class

Current time is determined by reading out a clock data maintained in the OBE that should be calibrated periodically.

7.2.4 Location class

In the case of road usage charging, vehicles should be charged on public roads and should not be charged on private roads. Location of chargeable roads and non-chargeable roads should be discriminated by GNSS positioning and map matching.

7.2.5 Traffic conditions

The traffic conditions, such as volume, speed, and occupancy can be detected with conventional vehicle detectors or GNSS based probe data

7.2.6 Summary

The technology used for realizing each component requirement of the charging function are shown in Table 7.

Table 7 — Technology for charging

Technology		Method	Description	Technical term or equipment
Functional requirements				
Distance driven	Should measure distance driven precisely.	Measurement with vehicle sensors directly	To collect distance driven data from odometer mounted in vehicle or tachograph	Odometer Tachograph
		Measurement with detecting road segments or entry/exit indirectly	To measure them by GNSS and map matching.	GNSS Map matching
			To measure them by DSRC, passive RFID or ANPR.	DSRC RFID ANPR
		Measurement with detecting road entry/exit and route	To measure them by DSRC and vehicle probe data	DSRC Vehicle probe data
Vehicle class	Should measure number of axles correctly.	Measurement of number of axles with on-road sensor	To measure number of axles with treadle or loop detector	Treadle Loop detector
		Measurement of number of axles with overhead sensor	To measure number of axles with laser or image sensor	Laser Image sensor
	Should measure vehicle weight precisely.	Measurement with weight sensor	To measure vehicle axle weight and/or gross weight with WIM	On-board WIM On-road WIM
	Should measure vehicle size precisely.	Measurement with overhead sensor	To measure vehicle length, width, and height with various sensors.	Laser, radar, lidar Image sensor
	Should detect emission class correctly.	Determine engine class	To read out engine class registered in OBE	n/a
User class	Should check the number of passengers.	Measurement with image sensor	To detect the number of passengers by image sensor	Image processing (trial stage)
Time class	Should vary charge rate from time to time.	To recognize present time/day with charge rate	To read out clock data maintained in OBE	n/a
Location class	Should charge on public roads and should not charge on private roads.	To discriminate between chargeable road and non-chargeable road	To discriminate between public road and private road assisted with GNSS and map matching.	GNSS Map matching
Traffic conditions	Should vary charge rate based on traffic conditions	To detect traffic conditions, such as volume, speed, and occupancy.	To detect traffic conditions with conventional vehicle detector or GNSS based probe data	Vehicle detector Probe data

7.3 Enforcement

7.3.1 Payment avoidance

There are two ways to enforce a vehicle that is judged to avoid payment at a tollbooth or at a charge point on the main line.

7.3.1.1 Force a vehicle to stop

At the tollgate, stop the vehicle that is judged to flee payment by automatic gate and do violation processing on the spot.

7.3.1.2 Automatic enforcement

At a charge point of the main line, identify a vehicle to have fled payment and recognize its number plate for enforcement later.

7.3.2 Over loaded

There are two methods to enforce a vehicle that is identified as overloaded at the toll gate or the charging point on the mainline.

7.3.2.1 Manual operation

To select a potential overloaded vehicle by human intervention and instruct it to go to a weigh station for assessing whether it is indeed overloaded.

7.3.2.2 Automatic enforcement

To identify an overloaded vehicle and recognize its number plate for enforcement later.

7.3.3 Summary

Techniques for realizing each component requirement of the enforcement function are shown in Table 8.

Table 8 — Technology for enforcement

Technology Functional requirements		Method	Description	Technical term or equipment
Payment avoidance	Should detect a payment avoidance vehicle	Force a vehicle to stop	To stop a payment avoidance vehicle physically	Automatic gate
		Automatic enforcement	To detect a payment avoidance vehicle and recognize its number plate for identification	Image processing Enforcement camera
Over loaded	Should detect an over loaded vehicle	Manual operation	To select a potential overloaded vehicle visually and instruct it go to weigh station	n/a
		Automatic enforcement	To detect an overloaded vehicle and recognize its number plate for identification	WIM Enforcement camera

7.4 Information provision

7.4.1 Tariff information

There are three methods to provide tariff information to users in accordance with charging policies.

7.4.1.1 Roadside equipment

To display existing tariff on roadside message sign board.

7.4.1.2 On-board equipment

To display existing tariff on on-board equipment.

7.4.1.3 Net service

To provide time-to-time detail tariff through net service.

7.4.2 Level of services (LOS)

There are two methods to provide level of services (LOS) to users in accordance with charging policies.

7.4.2.1 Roadside equipment

To display driving time to destination or assured speed on roadside message sign board.

7.4.2.2 On-board equipment

To display driving time to destination or assured speed on on-board equipment.

7.4.3 Charge amount

There are three methods to provide charge amount to users in accordance with charging policies.

7.4.3.1 Roadside equipment

To display charge amount on roadside message sign board.

7.4.3.2 On-board equipment

To display charge amount on on-board equipment.

7.4.4 Summary

Techniques for realizing each component requirement of the information provision function are shown in Table 9.

Table 9 — Technology for information provision

Technology Functional requirement		Method	Description	Technical term or equipment
Tariff information	Should inform users of the latest tariff information in a timely manner	Roadside equipment	To display existing tariffs on roadside equipment	Message sign board
		On-board equipment	To display existing tariffs on on-board equipment	OBE's HMI
		Net service	To provide time-to-time detail tariff through net service	n/a
LOS	Should inform user of present LOS related information in a timely manner	Roadside equipment	To display driving time to destination or assured speed on roadside equipment	Message sign board
		On-board equipment	To display driving time to destination or assured speed on on-board equipment	OBE's HMI
Charge amount	Should inform user of determined charge amount	Roadside equipment	To display charge amount on roadside equipment	Message sign board
		On-board equipment	To display charge amount on on-board equipment	OBE's HMI

8 Charging technologies

8.1 General description

Among the EFC technologies that realize the EFC function, charging technology is the most important, and it is classified as existing charging technology and new charging technology. In this document, the existing technology is defined as related themes already defined as being standardized and developed worldwide, and new charging technology is not standardized as EFC technology yet.

Communication technology such as DSRC is the core of charging technology, therefore comparison between DSRC and possible communication technologies, and the trend of other communication technologies are described in Annex C.

8.1.1 Eliminated EFC technologies or equipment

Among the EFC technologies or equipment listed in Tables 6, 7 and 8, the items described below are eliminated as future standardization items because they are deemed to be less relevant to the future charging policy and are inherently competitive market products.

8.1.1.1 Charging technologies and equipment

The following equipment and technology are eliminated from standardization targets:

— tachograph;

— map matching;

— treadle;

— loop detector;

— laser, radar, lidar;

— image sensor;

— vehicle detector.

8.1.1.2 Enforcement technologies and equipment

The following equipment and technology are eliminated as standardization targets:

— automatic gate;

— image sensor and processing;

— enforcement camera.

8.1.1.3 Information provision technologies and equipment

The following equipment and technology are eliminated from standardization targets:

— message sign board;

— OBE's HMI.

8.2 Existing technologies

8.2.1 DSRC

DSRC is defined as two way communication that is performed by either active (transceiver) method or backscatter (transponder) method defined in ITU-R M.1453-2[6].

DSRC is the essential communication technology for DSRC-based EFC because the major functions of charging, enforcement, and information provision are performed through DSRC where DSRC communication accuracy directly affects those of each item.

Functional structure and requirements for communication of DSRC-based EFC are shown on Figure 4 and in Table 10 respectively.

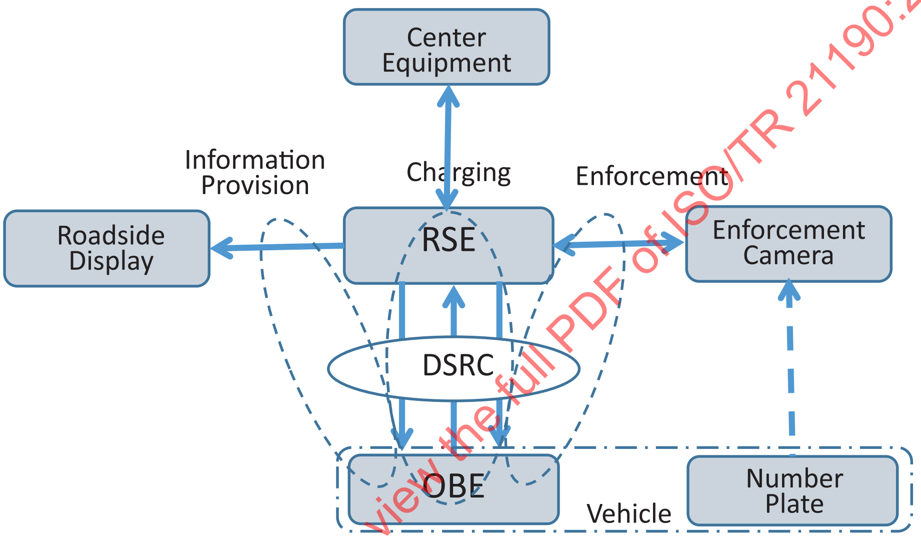

Figure 4 — Functional structure of DSRC based EFC

Table 10 — Requirements for communication of DSRC based EFC

Functions / Communication	Charging	Enforcement		Information provision		
		Payment avoidance	Over loaded	Tariff info.	LOS	Charge amount
1.Zone	Short	Short				Short
2.Data rate	High	High				High
3.Data volume	Mid.	Mid.				Mid.
4.Latency	Fast	Fast				Fast
5.Accuracy	High	High				High

[Note-1] blank cells denote n/a

8.2.2 Autonomous systems (GNSS/CN)

Autonomous systems charges road usage vehicles by identifying the vehicles passing at the charging points based on GNSS positioning and map matching. In the case of thin client charging is processed by back-end and charging amount is sent forward to OBE from back-end through CN in contrast with thick (smart) client where charging is processed by OBE and sent back to back-end from OBE through CN. In both cases enforcement is performed by DSRC because of being required short range communication.

Functional structure and requirements for communication of autonomous systems are shown on Figure 5 and in Table 11 respectively.

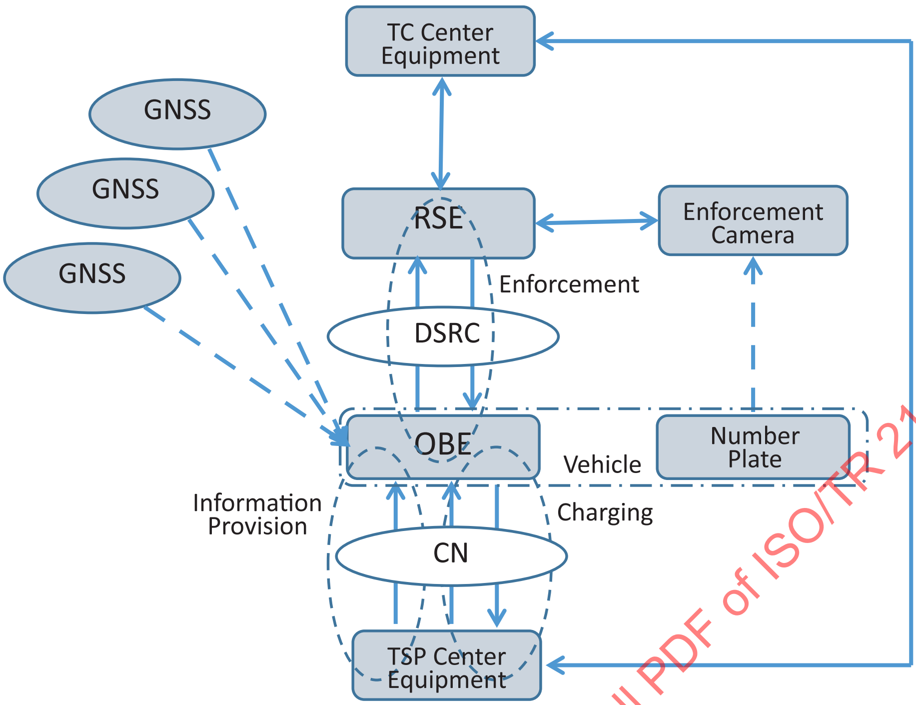

Figure 5 — Functional structure of autonomous systems

Table 11 — Requirements for communication in the case of autonomous systems

Functions / **Communication**	**Charging** (CN)	**Enforcement**		**Information provision**		
		Payment avoidance (DSRC)	Over loaded	Tariff info.	LOS (CN)	Charge amount
1.Zone	Wide	Short		Wide	Wide	Wide
2.Data rate	High	High		High	High	High
3.Data volume	Big	Mid.		Big	Mid	Mid
4.Latency	Mid	Fast		Mid	Mid	Mid
6.Accuracy	High	High		High	High	High

[Note-1] blank cells denote n/a

8.2.3 ANPR

A license plate is obliged to be attached to the vehicle by national law. While the style of license plate is standardized by country or region, there are several countries in which it is not standardized.

ANPR captures a still image of the license plate by digital camera, and reads the letters or numbers from the image by image processing technology, but there is a case to be erroneously recognized by such as bending of the dirt and plate. Since an erroneous recognition becomes a large obstacle for the system operations, the image processing technology has to be designed to minimize erroneous recognition to zero rather than enhancing the recognition rate.

In order to use the ANPR for charging as known as video tolling, the license plate information and the owner information should be registered to charging service providers with the payment type and the account information in advance. ANPR also has been employed for enforcement in many cases of EFC.

In order to improve the recognition rate, image processing techniques for processing a plurality of images and the fingerprint-matching technology have been reported, but it is necessary to improve the recognition rate and minimize the false recognition by human operators.

However, there are operational challenges remaining to cope with forgery of the license plate and to be able to access to the database in which vehicle owner's information is registered in order to identify the vehicle owner by license plate information.

Functional structure of ANPR based EFC is shown on Figure 6.

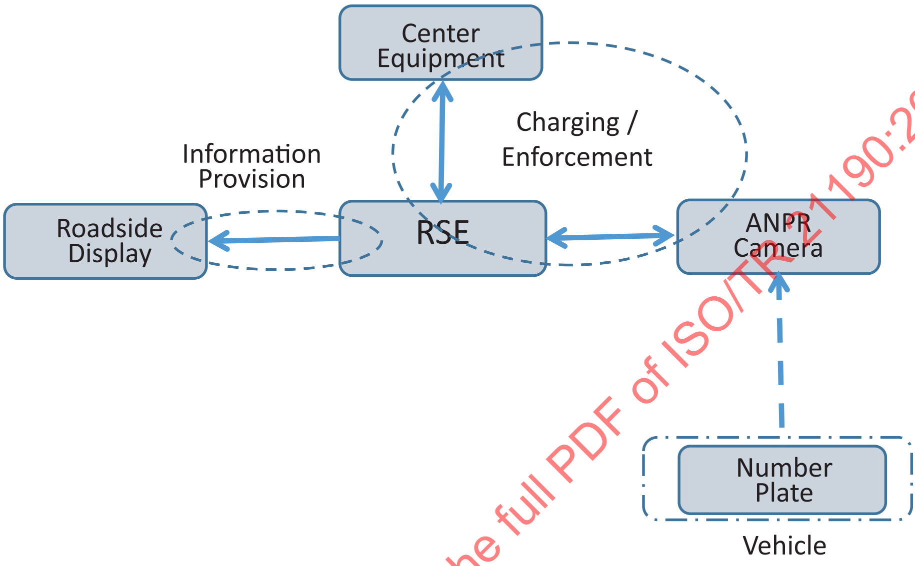

Figure 6 — Functional structure of ANPR based EFC

8.3 Emerging technologies

8.3.1 Probe data

In the route selection system, GNSS positioning data stored in OBE is transferred to the back-end through emerging DSRC roadside units as probe data that is similar to thin client system of autonomous systems, however communication method is not CN but DSRC. Probe data is used to identify the travelling route and charging is performed by the conventional DSRC roadside units.

Route selection systems taking advantage of this probe data are also regarded as an extended type of DSRC based EFC, therefore a subsequent development of the transition to the autonomous systems will become easier. The functional structure of probe data supported EFC is shown on Figure 7.

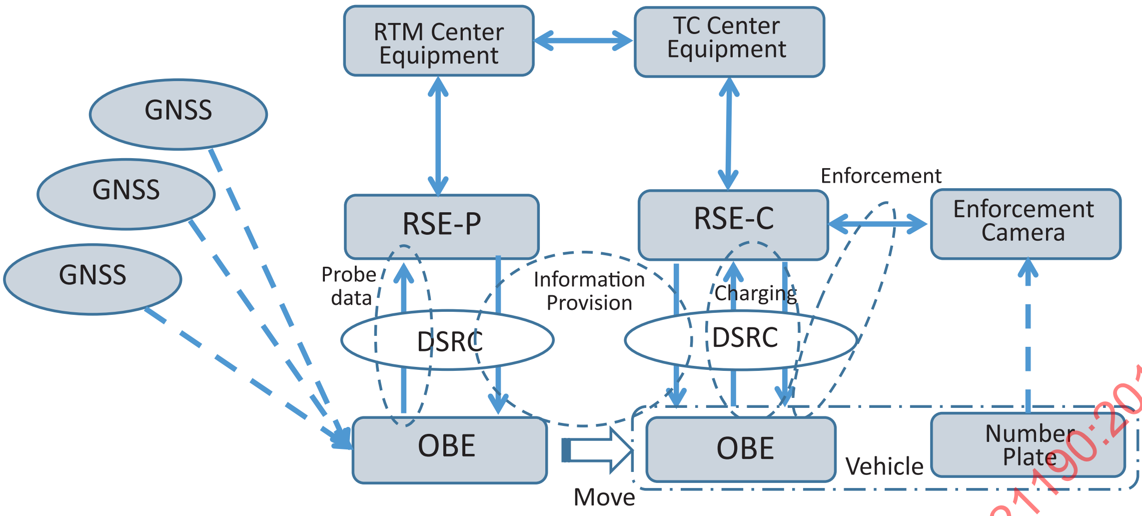

Figure 7 — Functional structure of probe data supported EFC

8.3.2 Odometer

The odometer was originally used to record the total traveling distance of a vehicle and is useful for charging applications by reading its data from the on-board diagnostics (ODB-II) port. This data can be used for road usage charging in conjunction with GNSS positioning and map matching to identify the chargeable roads or not. The functional structure of odometer based EFC is shown in Figure 8.

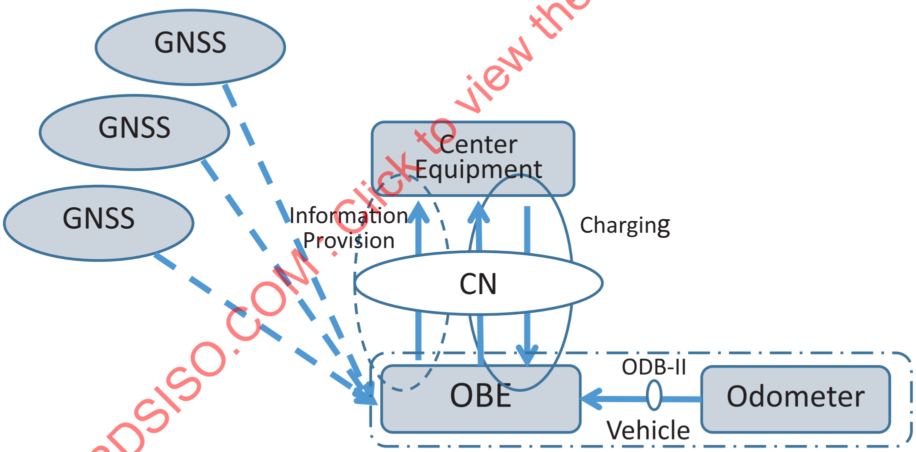

Figure 8 — Functional structure of odometer based EFC

8.3.3 Passive RFID

While passive RFID has been developed originally for identifying goods with a means of a unique electronic product code (EPC) and to replace the bar code in the supply chain industry, it has been improved and standardized as ISO/IEC 18000-63 (referred to as passive UHF RFID in this document) that provides one/two way communication with no inner battery aiming at cost effective EFC.

Though there has been in the past a problem of low security to be used for EFC, the recent standardization of ISO/IEC 29167 extends passive RFID with different optional cryptographic suites, e.g. AES-128. These cryptographic suites embedded on a passive RFID tag allows already today actual tag authentication, encrypted communication on the air link and in the future also mutual authentication of passive RFID tag and reader.

In principle it is also possible to write and store transient EFC related data on the vehicle tag at the roadside, but with the existing available passive RFID tag chips it can be problematic at high vehicle speed. Therefore in nearly all EFC applications transient EFC data are stored and kept up-to-date in the back office and at the roadside the passive RFID tags are only read.

Functional structure and requirements for communication of passive-RFID-based EFC are shown in Figure 9 and in Table 12 respectively.

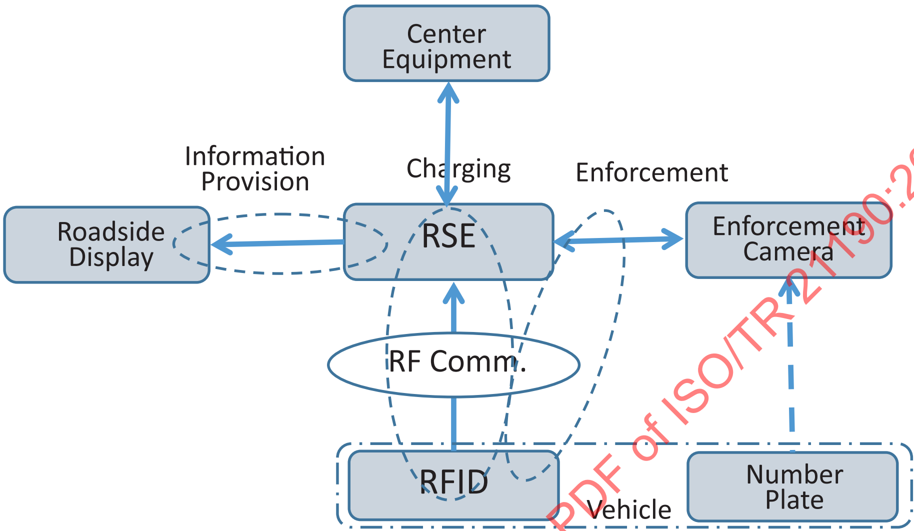

Figure 9 — Functional structure of RFID based EFC

Table 12 — Requirements for communication of passive-RFID-based EFC

Functions / Communication	Charging	Enforcement		Information provision		
		Payment avoidance	Over loaded	Tariff info.	LOS	Charge amount
1.Zone	Short	Short				
2.Data rate	Mid	Mid				
3.Data volume	Short	Short				
4.Latency	-	-				
5.Accuracy	Mid	Mid				

RFID

[Note1] blank cells denote n/a

8.3.4 WAVE

WAVE is a generic term of collective IEEE 802.11p and IEEE 1609 series of standards developed for safety driving support called C-ITS.

As there is a possibility that C-ITS equipment will be deployed globally in the near future, the past work item of TR "Guideline for EFC applications based on in-vehicle ITS station" was developed and issued with consideration of being applied to the EFC.

Functional structure and requirements for communication of WAVE based EFC are shown in Figure 10 and in Table 13 respectively.

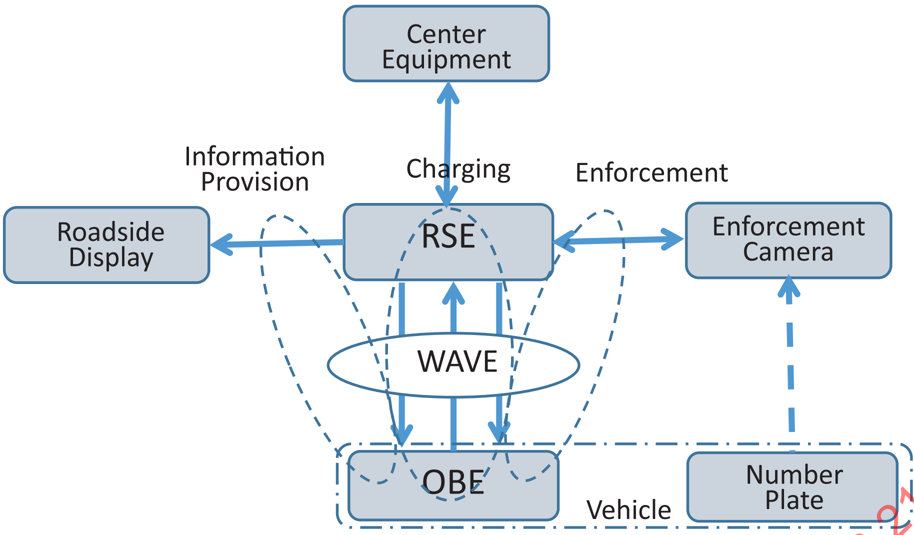

Figure 10 — Functional structure of WAVE based EFC

Table 13 — Requirements for communication of WAVE based EFC

Functions / Communication	Charging	Enforcement		Information provision		
		Payment avoidance	Over loaded	Tariff info.	LOS	Charge amount
	WAVE					WAVE
1.Zone	Short	Short				Short
2.Data rate	High	High				High
3.Data volume	Mid	Mid				Mid
4.Latency	Fast	Fast				Fast
5.Accuracy	High	High				High

[Note1] blank cells denote n/a

IEEE 1609.11 defines the protocols for applying WAVE to EFC (WAVE based EFC) in Annex A where EFC standards of ISO 14906 and ISO 15628 are mapped on WAVE stack as shown on Figure 11.

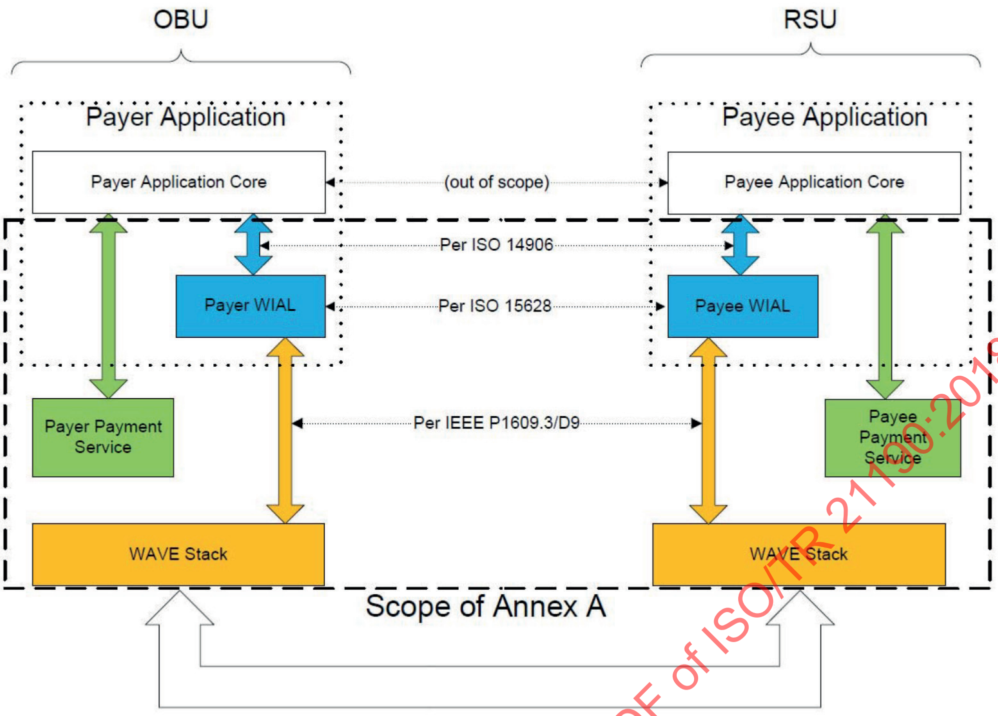

Figure 11 — EFC application on WAVE stack (Source: IEEE 1609.11)[5]

Also in order to apply the WAVE to CCC and the LAC, the revision work of ISO 12813 and ISO 13141 has been carried out. Functional structure is shown on Figure 13.

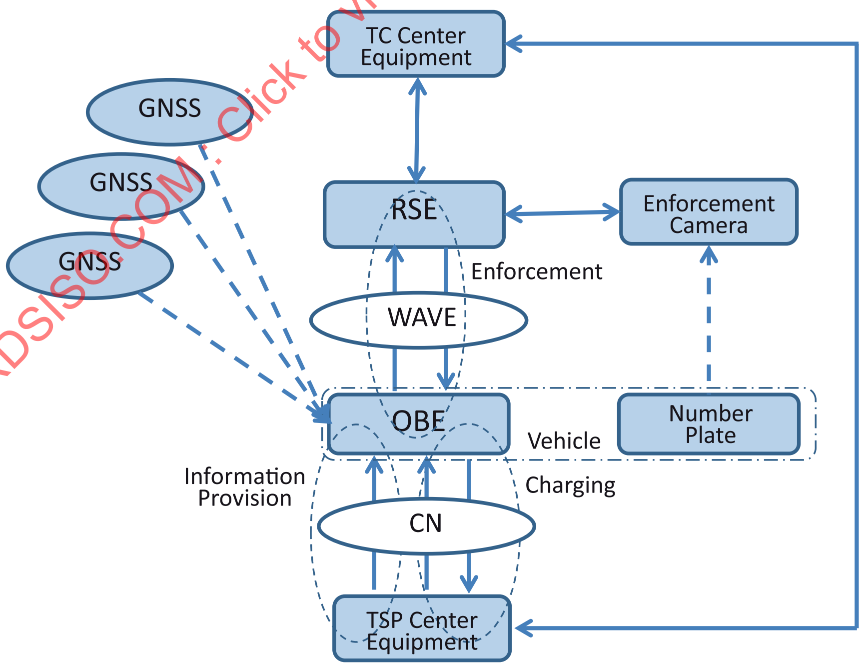

Figure 12 — Functional structure of Autonomous systems with WAVE

8.3.5 WIM

WIM is used to detect overloaded vehicles traveling on toll roads or non-toll roads in many countries and to impose penalties. In recent years, WIM has been developed to accurately measure the axle load or gross weight of high-speed vehicles, so in some countries the legal system has been revised so that direct fines can be processed by dynamic load measurement data. A.7 briefly shows direct enforcement.

It may also be applied to a new charging policy aiming at fairness of the charging rate such as toll-by-weight that collects a charge proportional to the actual weight of the vehicle using WIM that can be measured accurately.

Functional structure of toll-by-weight is shown on Figure 13.

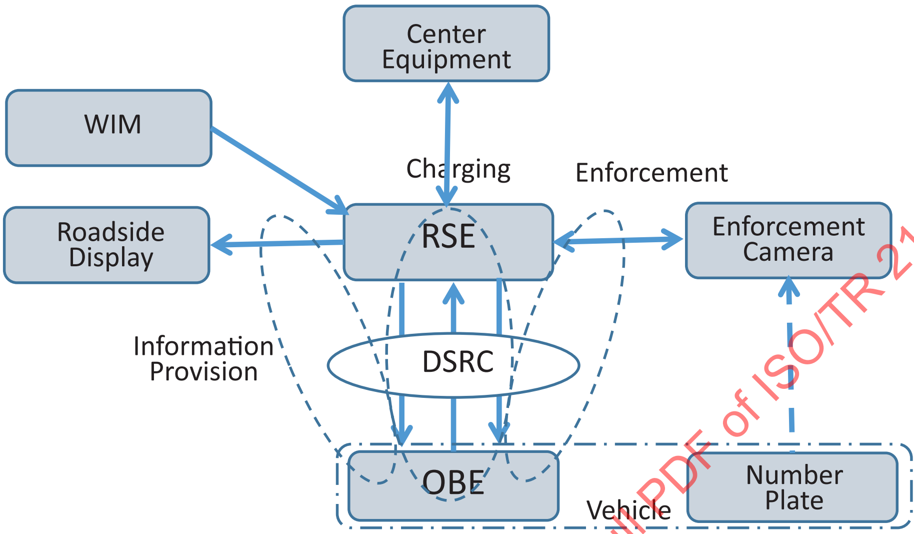

Figure 13 — Functional structure of toll-by-weight

8.3.6 Other technologies

In addition to the above-mentioned technologies, the following communication technologies and signal authentication technologies of GNSS are currently being researched and developed and are about to be put to practical use. These techniques are effective for improving the charging performance in the charging function and the safety of positioning information.

8.3.6.1 Bluetooth

Bluetooth uses radio waves in the 2,4 GHz band and is used for simple information exchange between information terminals by short distance communication. It is suitable for use in a constantly connected state between information terminals, however strict control of transmission and reception and confidentiality are not taken into consideration so much.

8.3.6.2 CN-5G

The fifth generation mobile communication system (5G) is not only "super high speed", but also a new generation of mobile communication system having features such as "multiple simultaneous connection" and "low delay/high reliability", and realization around 2020 development and demonstration is being actively promoted in various countries around the world as a goal.

8.3.6.3 A-GNSS

Signals of GNSS are known to be disturbed by spoofing etc. and become erroneous positioning data, and existing prevention measures are being studied by research institutes in several countries. Among them, a method of adding authentication information to the GNSS signal and authenticating with the vehicle-mounted device that has received the authentication information separately by road-to-vehicle communication has been proposed[11].

8.4 Consideration of mutual applicability

8.4.1 General

The charging policy implemented as a road traffic policy, the charging technology realizing this, and its relation are as described in the previous clauses. There are some charging policies that have been implemented and those planned to be implemented, and the policy objectives have become more consistent with the needs of society. In this clause, how the conventional technology and the emerging technology realize the integrated charging policy of the existing and the emerging ones is examined.

As the emerging technology, potentially possible technology that has not been planned or experimented as a charging technology so far is included.

8.4.2 Existing technologies for new charging policies

Existing EFC technologies that can be applied for the emerging EFC policies are:

— ANPR;

— DSRC;

— Autonomous systems (GNSS, CN-3G/4G).

8.4.3 Emerging technologies for conventional charging policies

Emerging NFC technologies that can be applied for the conventional policies are:

— passive (UHF) RFID;

— odometer;

— Bluetooth;

— CN-5G;

— A-GNSS.

8.4.4 Emerging technologies for new charging policies

Emerging EFC technologies that can be applied for the emerging EFC policies are:

— passive (UHF) RFID;

— WAVE;

— odometer;

— vehicle probe data;

— WIM;

— Bluetooth;

— CN-5G;

— A-GNSS.

Table 14 shows the results of organizing the relationship between the charging policy and the EFC technology.

Table 14 — Relation between charging policy and EFC technology

Policy objectives	Policies	EFC technology			
		Existing technology		Emerging technology (incl. potential tech.)	
		Communication	Others	Communication	Others
1. Financial source for road construction and/or maintenance	To raise funds for repaying loans of road construction by charging	DSRC CN-3G/4G	GNSS (ANPR)	CN-5G A-GNSS	n/a
	To raise funds for repaying loans of road construction by charging with low cost equipment.	n/a	ANPR	Passive UHF RFID Bluetooth	n/a
	To raise funds for repaying loans of road construction by charging with C-ITS equipment.	n/a	(ANPR)	WAVE	n/a
	To raise funds for road maintenance or reconstruction by charging for HGV	DSRC CN-3G/4G	GNSS (ANPR)	CN-5G A-GNSS	Odometer
	To raise funds for road maintenance or reconstruction by charging as alternative for fuel tax.	CN-3G/4G	GNSS	CN-5G A-GNSS	Odometer
2. Traffic management by charging	To reduce congestion in urban roads by charging.	DSRC CN-3G/4G	GNSS (ANPR)	CN-5G A-GNSS	Odometer
	To provide appropriate route in a metropolitan area for users by dynamic charging.	DSRC	GNSS	n/a	Vehicle probe data
	To provide appropriate lane in inter-urban roads for users by dynamic charging.	DSRC	n/a	RFID	n/a
3. Internalizing external costs	To charge all vehicles based on the accidents, delays, noise, pollution and road wear each vehicle imposes on the society and other vehicles.	DSRC	GNSS (ANPR)	Passive UHF RFID	n/a
4. Fair charging rate	To define charging rate based on a gross vehicle weight	DSRC	n/a	n/a	WIM

NOTE 1 Shaded parts are the emerging charging policy.

NOTE 2 ANPR: used for charging, (ANPR): used for compliance checking.

9 Recommendations

9.1 General

As mentioned in Clause 6, the EFC function is composed of charging, enforcement, information provision, and payment function, and with the progress of communication technologies, information security technology, image processing technology, sensing technology, etc. related to these, each function is evolving so that it can deal with new policies.

Eight new EFC related themes reflecting the existing or the emerging technologies are nominated to be evaluated for the future standardization work themes hereinafter.

9.1.1 Evaluation criteria

These new theme candidates are evaluated from the viewpoints of both the necessity of market and the existence of standards.

9.1.1.1 Market need level

Market need level is classified into three stages as follows.

— There are specific needs at the global level toward introduction.

— There are specific needs at the regional level and national level toward introduction.

— There are no specific needs at the moment, but there is a potential need in the future.

9.1.1.2 EFC standardization level

The standardized level is classified into the following four stages.

— Essential technology and related matters are standardized, but they are not standardized for EFC.

— EFC standardization is in drafting.

— EFC standardization was already done.

— EFC standardization is dormant after consideration.

9.1.1.3 Class definition

The evaluation matrix is shown in Table 15 and each class is defined as below.

— Class A: There is a necessity on the global scale, and since there is no EFC standard, standardization work is urgent.

— Class B: Since there is a necessity at the regional or national level and there is no EFC standard corresponding to it, we will consult with the representative of the region or the country and decide whether to consider it as a standardization theme.

— Class C: There is a potential necessity, but there is no EFC standard corresponding to this, so judge whether it will be taken up as a standardization theme by WG.

— Class X: There is a necessity of the global, regional or national level, and the theme is still undergoing standardization work.

— Class Y: The theme that has the necessity of the global, regional or national level and has already been standardized work.

— Class Z: The theme that needs the global, regional or national level but the standardization work is dormant.

Table 15 — Evaluation matrix for recommendations

Need level EFC standard	Globally	Regionally or nationally	Potentially
None	Class A	Class B	Class C
In Drafting	Class X	Class X	n/a
Done	Class Y	Class Y	n/a
Dormant	Class Z	Class Z	n/a

9.2 Evaluations

9.2.1 Charging assist traffic management

Though urban congestion charging, route selection fee and express lane on intercity roads have been implemented or planned differently so far, a common function model to respond to the same policy objective of controlling traffic flow by charging is under consideration.

Therefore a theme to define a suitable common functional model to apply EFC to traffic management and interfaces between related entities are recommended as a new standard. However this emerging work item was already proposed and has been drafted now so that recommendation class should be Class X.

9.2.2 Passive UHF RFID-based EFC

Passive UHF RFID-based EFC is increasingly being demanded in developing countries as it can provide a cost-effective EFC system for even high-speed vehicles on the highway main line. Passive RFID was originally developed for supply chain product management as a substitute for the barcode label, and operates without battery.

For this reason, information exchange between passive RFID-tag and the reader (interrogator) is normally done in plain text and it can be easily deciphered, so that security and privacy issues should be considered for applying to EFC. As a security measure for passive RFID, the necessity and framework of security measures are defined in ISO/IEC 29167-1[2], and a security mechanism using AES-128 is defined in ISO/IEC 29167-10[3].

In addition, standardization of data definition is carried out for the supply chain system, but for EFC, road operators define data respectively and it does not have interoperability. Therefore, standardization of data definitions is necessary so that interoperability becomes possible.

Considering the above, the recommended class should be Class B.

9.2.3 Odometer-based EFC

The odometer is an essential sensor mounted on the vehicle and can be effectively used in road usage charging as well as in other charging systems for distance based charging systems by measuring the distance travelled directly. The mileage data from odometer can be obtained by connecting the in-vehicle terminal to the OBD-II port of the vehicle, but because the interface is disclosed with the ISO 15765 series of standards, security measures against mileage data falsification are necessary.

In addition, it is assumed that system configuration and data exchange between entities may be different from existing ISO 17573 "EFC Architecture", and it is necessary to study the system architecture for the odometer-based EFC.

Therefore, odometer-based EFC is recommended as a new standardizing theme, but some social experiments aiming at practical applications have been conducted in the United States only. For international standardization, cooperation with experts from the United States is necessary, and further investigation as to whether there is a need in other regions or countries outside the United States is necessary. For this reason the recommended class should be Class B.

9.2.4 ANPR based EFC

ANPR-based EFC is used to supplement of DSRC-based EFC, such as charging for vehicles that do not have OBE, or in the case where using OBE is difficult. It is also used for compliance checks, and specifications and test standards are established in each of the introduced countries.

Since the recognition result of ANPR is used for enforcement purposes as well as charging, it is necessary to prevent from tampering the license plate character recognition result and the image data as evidence, and there is a possibility as a theme candidate for standardization.

Because ANPR is already in operation in each country and the necessity of international standardization is not high, it is better to hold it back as a standardization theme for a while, so that recommendation class should be Class Z.

9.2.5 Toll-by-weight

Damage to road pavement is said to be proportional to the fourth power of shaft weight, and it is also said that there is further influence on steel structures of elevated roads and bridges. The toll fee structure is ideal considering axle weight or gross weight for toll fee, and introduction is done in some countries (see A.6).

After the introduction as an effect that the traffic of overloaded vehicles has decreased has been reported, and on expressways in large cities with many elevated roads and bridges, weight-based charging is being considered for extending their service life. Therefore, it is estimated that there are many needs as a new standardization theme, and the recommended class should be Class B.

9.2.6 WAVE based EFC

In order to support vehicle safety driving, C-ITS has been developed and introduced in various areas of the world, and has been planned to be obliged as standard equipment of new cars in the United States. The communication technology used in C-ITS is called WAVE generally and can be applied to road charging in common to be expected that introduction of WAVE based EFC will become popular in accordance with expanding C-ITS. However, since the WAVE-based EFC is already defined in IEEE 1609.11, the recommended class should be Class Y.

9.2.7 CN-5G for EFC

The fifth generation mobile communication system (5G) is not only "super high speed", but also a new generation of mobile communication system having features such as "multiple simultaneous connection" and "low delay/high reliability", and realization around 2020 development and demonstration etc. are being actively promoted in various countries around the world as a goal.

When CN-5G is used in the autonomous system, it becomes possible to notify OBE of the charging amount decided by the central system within a short time delay. For this reason, it is assumed that autonomous systems will further spread as a result of realizing lower cost OBE used for thin client.

It is also conceivable to send the A-GNSS authentication data to the OBE via the CN-5G, so that highly reliable positioning data can be acquired. Considering these potentialities, the recommended class should be Class C.

9.2.8 A-GNSS for EFC

Signals of GNSS are known to be disturbed by spoofing etc. and become erroneous positioning data, and existing prevention measures are being studied by research institutes in various countries. Among them, a method of adding authentication information to the GNSS signal and authenticating with the vehicle-mounted device that has received the authentication information separately by road-to-vehicle communication has been proposed.

Although concrete implementation design is expected to be a future work, it is potentially an important technology to support high reliability of road charging, so the recommended class should be Class C.

9.3 Summary

Table 16 shows a summary of the above investigation results.

Table 16 — Recommendation for future standardization

Recommended theme	Deployment	Degree of demand	Scope to be standardized	Recommended class for standardization
1. Charging assisted traffic management	USA, Singapore, (Japan)	High demand for traffic management in urban roads or inter-urban roads globally.	— Generic model — Data definition	Class X
2. RFID based EFC	Taiwan, India, and other area	High demand in developing or other countries generally.	— EFC data definition — Security mechanism	Class B
3. Odometer based EFC	(USA)	High demand for alternative fuel tax in USA.	— Security countermeasure for the distance driven data of odometer — System architecture	Class B
4. ANPR based EFC (Video Tolling)	Stockholm, USA, etc.	High demand for charging without OBE globally.	— Secure image — Evidence	Class Z
5. Toll-by-weight	China	Potential demand for Toll-by-weight globally.	— High accuracy type WIM	Class B
6. WAVE based EFC	USA (Korea)	Potential demand for charging in accordance with popularizing C-ITS.	— Boundary of responsibility in-vehicle C-ITS equipment	Class Y
7. CN-5G for EFC	n/a	Potential demand for enhancing performance of CN.	n/a	Class C
8. A-GNSS for EFC	(Europe) (Japan)	Potential demand for enhancing security of GNSS signal.	n/a	Class C

NOTE 1 Countries in parentheses are planning to implement in the near future.

Annex A
(informative)

Application of technology to EFC systems

A.1 General

Table A.1 shows how the technology or equipment is applied to EFC systems.

Table A.1 — Application of technology to EFC systems

Technology		EFC system	Base-STD or alike document	EFC-STD	Common name	Deployments	Ref
DSRC		DSRC-based EFC	ITU-R M.1453.2 (CEN,UNI, ARIB,T-TA) ISO 15628	ISO 14906	ETC	Europe Asia South America Australia etc.	n/a
					HGV charging	Austria Czech Poland	n/a
			(National STD)	(Nat.-STD)	ERP	Singapore	n/a
GNSS	CN	Autonomous systems	IMT-2000 IMT-Advanced	ISO 17575	HGV charging	Germany Slovakia Belgium Russia	n/a
	Tachograph	Autonomous systems	n/a	ISO 14906	LSVA	Switzerland	n/a
	DSRC	Probe data supported EFC	n/a	n/a	Smart route selection	Japan	A.2
	Odometer	Odome-ter-based EFC	ISO 15765-4 (CAN)	n/a	RUC	USA	A.3
Passive UHF RFID		Passive UHF RFID-based EFC	ISO 18000-63	n/a	ETC	India Taiwan, etc.	A.5
ANPR		ANPR-based EFC	n/a	n/a	Congestion charging	Stockholm	n/a
WAVE		WAVE-based EFC	IEEE 802.11p	IEEE 1609.11	n/a	USA	A.4
WIM		Toll-by-weight	ASTM E-1318, OIML R-134	n/a	n/a	China	A.6 A.7
Smart phone		Mobile tolling	n/a	n/a	n/a	USA	A.8

A.2 Smart route selection in Japan

A.2.1 General

In the greater Tokyo metropolitan area, the construction of outer ring expressways will be almost finished in a few years for aiming at reducing traffic congestion in the central Tokyo area. In the complex network consisted of three ring expressways and nine radial expressways, a user can select a suitable route with consideration of traveling time and toll amount.

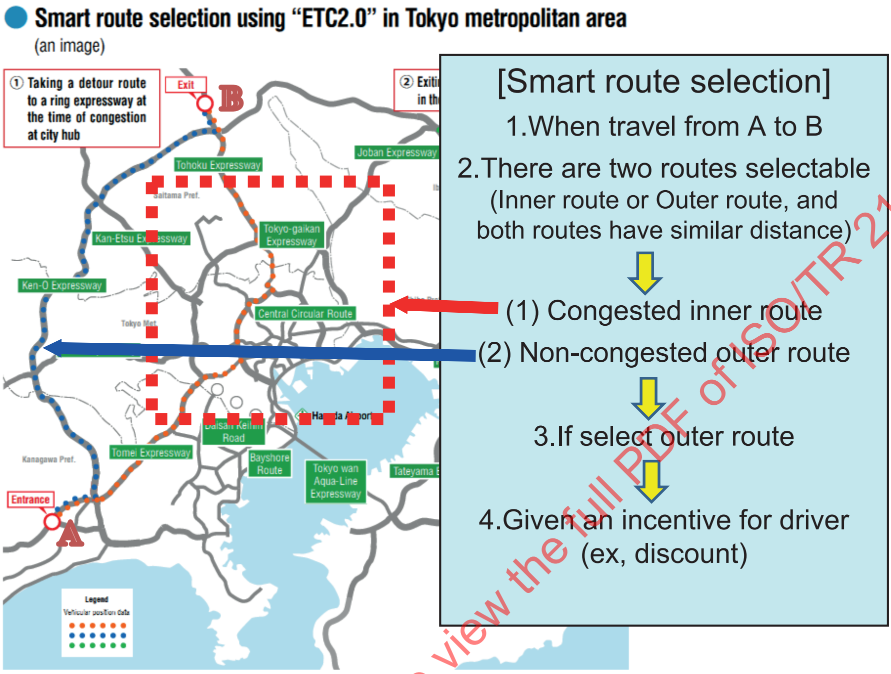

Figure A.1 — Image of smart route selection in Tokyo metropolitan area (Source: MLIT in Japan)

A.2.2 System configuration

The tolling system consists of DSRC-OBE with a GNSS receiver, RSE for tolling, RSE for probe data/traffic information, and each central equipment for toll service provider and road manager as shown below.

RSE for tolling is installed at each entry lane and exit lane as the same as present tolling system. The other type of RSE, installed on expressways, provides route information and uploads GNSS based probe data from OBE. A toll amount determined by the combination of entry, selected route and exit is settled so as to advise a vehicle to avoid congestion in the central Tokyo region.

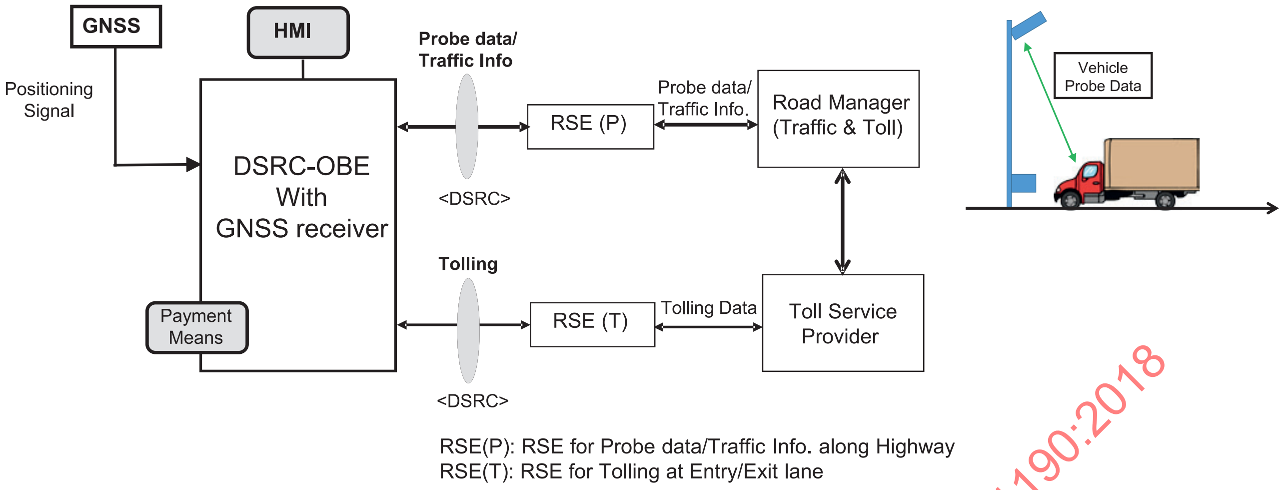

Figure A.2 — System configuration of smart route selection

A.3 Road usage charging in USA

In Oregon USA, Road Usage Charging (RUC) based on odometer has been studied since 2001 to deal with decreasing fuel tax revenue along with popularity of high efficiency vehicles and electric vehicles.

A large scale field operation test will be started on 1 July with 5,000 vehicles.

The same RUC scheme is considered to be implemented in the western states of the USA including California and Washington to keep abreast with Oregon.

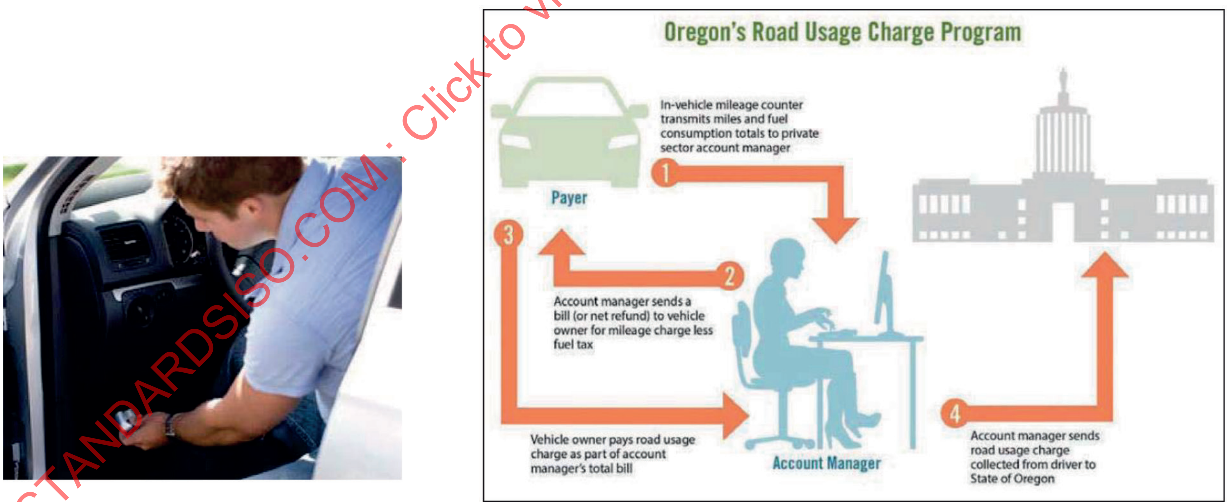

Figure A.3 — Operation flow of RUC in Oregon USA (Source: Oregon DOT)

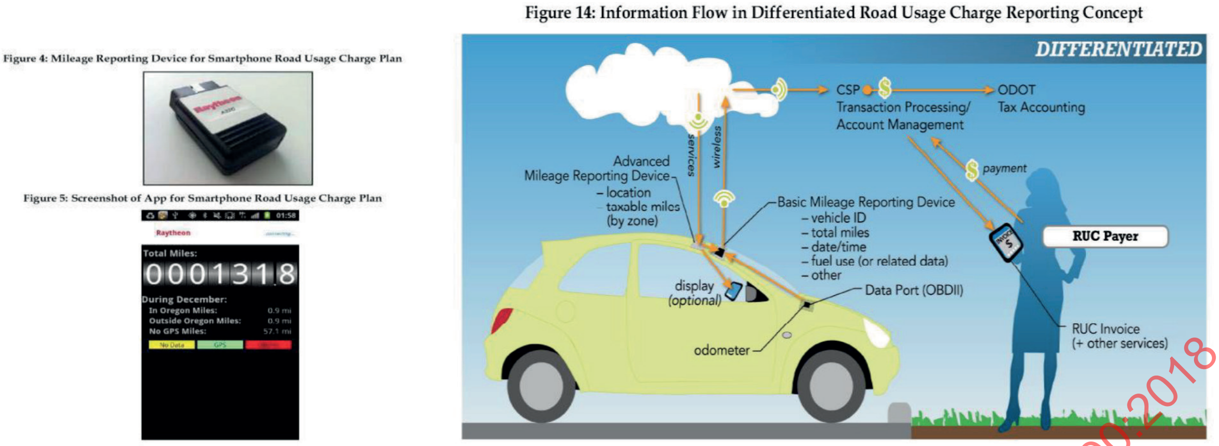

Figure A.4 — Data flow of RUC in Oregon USA (Source: Oregon DOT)

A.4 WAVE based EFC in Korea

In Korea DSRC based EFC has been operated since 2007 where conventional single lane tolling method is implemented. In 2014 emerging a multi-lane tolling method was implemented and has been operated up to now to improve throughput at Busan West toll plaza.

At Seoul toll plaza WAVE based EFC was tested to evaluate charging performance and to foresee expendabilities toward C-ITS (V2X).

a) Smart tolling with conventional DSRC **b) Smart tolling with WAVE**

Figure A.5 — WAVE based EFC in Korea (Source: KEC in Korea)

A.5 RFID based EFC in Taiwan

Although IR-based EFC was introduced in Taiwan highways in 2006, OBE has not been as popularized as expected due to its cost. The Taiwanese government decided to replace IR based EFC with RFID based EFC where the cost of RFID was much less than IR based OBE.

An emerging tolling system has been operated since December 2013 with 319 charging gantries and five million subscribers.

a) RFID and charging gantry at the main line

b) Highway network in Taiwan (900 km)

Figure A.6 — RFID based EFC in Taiwan (Source: FETC & TANFB in Taiwan)

A.6 Example of toll-by-weight in China

A.6.1 General

A breakthrough charging scheme based on vehicle weight and distance driven for heavy good vehicles called "toll-by-weight" has been introduced nationwide to highways in China. The toll bay weight scheme has been applied for only manual toll collection not for ETC that heavy good vehicles are not allowed to use.

WIM is installed at the entry side of manual exit toll gate where a heavy goods vehicle is measured by its gross weight in the course of moving to the toll booth. A charge amount is determined based on the travel distance by reading from ticket information issued at the entrance toll gate and gross weight is measured at the exit toll gate, and then the determined charge amount is collected by the toll collector.

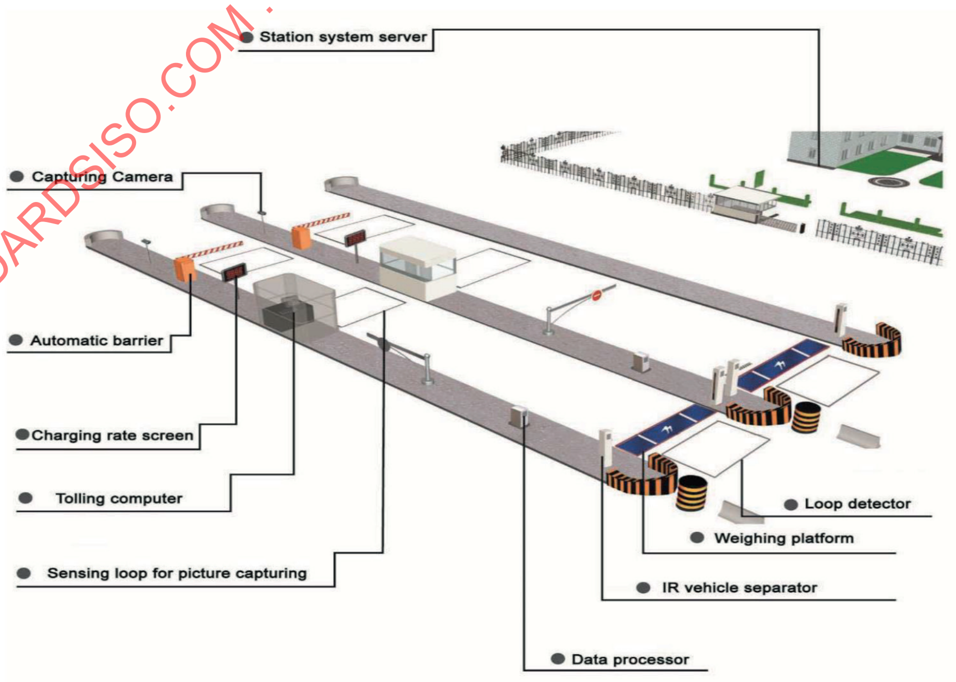

Figure A.7 — Overview of exit lane equipped with WIM (Source: Wanji technology in China)

A.6.2 Charge rate

Although the charging amount is determined based on the vehicle weight and the travel distance, the charging unit price is different from region to region and highway. In addition, a penalty for overloaded vehicles that is proportional to the overloaded weight is collected by the toll collector.

A.6.2.1 Example (T city)

A.6.2.1.1 Basic charge rate

Unit charge rate is a flat rate of 0,10 (yuan/ton-km) for HGV less than 14 t, and decreases linearly until the HGV is less than 50 t. For reference, each charge rate for HGV is listed on the right column in Table A.2. However, in the case of an HGV less than 5 t, the charge rate is the same as that of 5 t.

Table A.2 — Charge rate for HGV

Vehicle gross weight ton (t)	Unit charge rate (yuan/ ton-km)	Remarks	Example charge rate (yuan/km)	
Less than 5 t	0,10	Fixed (not depends on weight)	3 t	0,5
			4,5 t	0,5
5 t to 14 t	0,10	Depends on weight	5 t	0,5
			10 t	1,0
14 t to 25 t	0,10 to 0,07	linearly decreasing and depends on weight	14 t	1,4
			20 t	1,73
25 t to 50 t	0,07 to 0,04	linearly decreasing and depends on weight	25 t	1,75
More than 50 t	0,04	Fixed (does not depend on weight)	50 t	2,0
			90 t	3,6

A.6.2.1.2 Overcharge for overloaded vehicles

For overloaded vehicles, it is added as an overloaded charge to the normal charge amount and collected. The overloaded fee is set according to the overloading ratio as shown in Table A.3, and it does not apply to the overload rate of 30 %.

Table A.3 — Overloaded charge rate

Overloaded class (%)	Overloaded charge (yuan/ton-km)	Remarks
within 30 %	n/a	No overcharge applied
30 to 50 % less	0,10	—
50 to 80 % less	0,15	—
80 to 100 % less	0,20	—
more than 100 %	0,40	—

A.6.2.1.3 Method of calculation for the weight charges

The toll payment for normal vehicles shall be:

Gross weight × Unit charge rate × Vehicle miles travelled.

Overloaded charge amount should be:

Overloaded weight × Overloaded charge of identified class × Vehicle miles travelled

The toll payment for overloaded vehicle shall be:

Normal toll charge + Overloaded charge

A.7 Direct enforcement in Czech Republic

In 2012 the Czech Republic adopted an amendment to Act No. 13/1997 Coll. on Roads as amended and thereby was one of the first in the world to take a decisive legislative step for direct recourse of operators of overloaded vehicles based on the application of high-speed weighing technology (WIM, “Weighting in Motion”).

When adhering to the relevant certification, it will no longer be necessary to weigh a vehicle on mobile scales, the vehicle will only be subject to weighing in motion.

A detailed method must be determined of the implementation of high-speed weighing and also grant persons providing WIM, legal authorisation for access to the central vehicle register for the purpose of identifying the operator according to vehicle registration number plates so that this person can, without any legal obstacles, identify the operator of the relevant vehicle based on the information obtained from the road vehicle register.

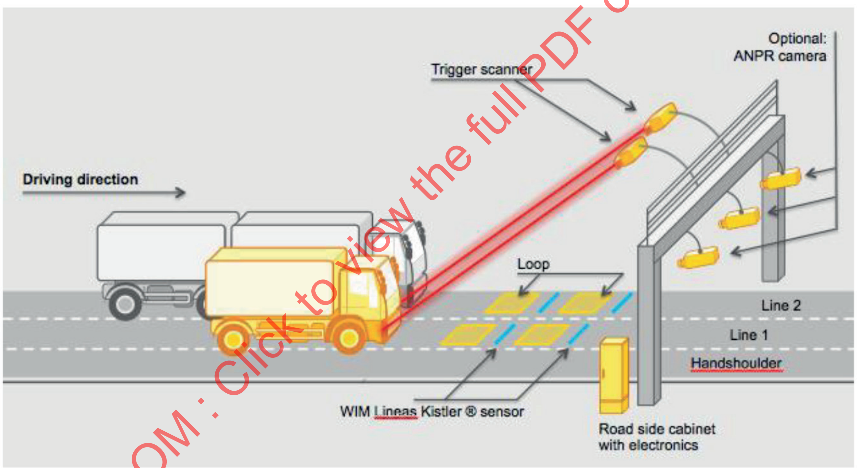

Figure A.8 — Direct enforcement in Czech Republic (Source: ITS world congress 2016)[9]

A.8 Mobile tolling

The emergence of smartphones has led to a multitude of traffic-related applications over the past years. In the USA, already two thirds of all citizens and 85 % of all millennials (Generation Y) own a smartphone and two-thirds out of these smartphone owners use their smartphone at least occasionally for turn-by-turn navigation while driving.

At the same time, the number of All Electronic Tolling (AET) systems for toll collection is increasing worldwide. In the USA, manual toll plazas are converting to AET systems and more and more managed lanes projects are started. A solution in Illinois is already operational and offers mobile toll payments through the application by accessing open payment interfaces provided by the webpage of the toll agency and charges road users a convenience fee for paying through the smartphone application.

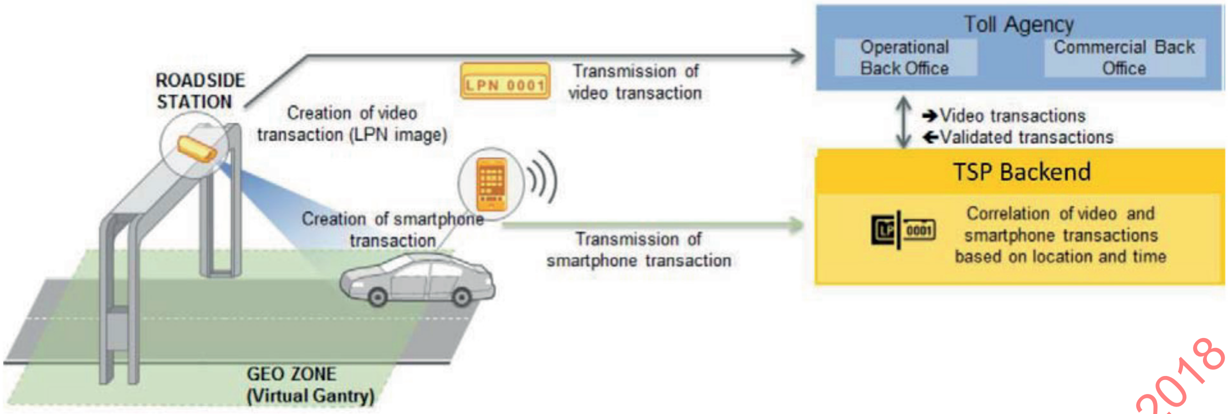

Figure A.9 — Mobile tolling (Source: ITS world congress 2017)[10]

Annex B
(informative)

Example of tariffs

B.1 Example of tariffs

B.1.1 HGV charging in Germany

The charging unit price per kilometre in Germany is set according to the engine class and the number of axles, as shown in Table B.1.

Toll rates per kilometre as of October 1, 2015		
Category	Emission class / number of axles[1]	Toll rate
A	**S6, Euro 6**	
	2 axles	0,081 €
	3 axles	0,113 €
	4 axles	0,117 €
	5 axles and more	0,135 €
B	**S5, EEV[2] Class 1, Euro 5, EEV Class 1**	
	2 axles	0,102 €
	3 axles	0,134 €
	4 axles	0,138 €
	5 axles and more	0,156 €
C	**S3 with min. PMK[3] 2, S4, Euro 3 with min. PMK 2, Euro 4**	
	2 axles	0,113 €
	3 axles	0,145 €
	4 axles	0,149 €
	5 axles and more	0,167 €
D	**S2 with min. PMK 1, S3, Euro 2 with min. PMK 1, Euro 3**	
	2 axles	0,144 €
	3 axles	0,176 €
	4 axles	0,180 €
	5 axles and more	0,198 €
E	**S2, Euro 2**	
	2 axles	0,154 €
	3 axles	0,186 €
	4 axles	0,190 €

Figure B.1 — Tariff on HGV charging in Germany (as of 2015)

NOTE Figure B.1 is a table taken from "https://www.ages.de/en/hgv-toll-germany-tariffs.html".

B.1.2 Urban congestion charging in Singapore

The charging amount of urban congestion charging in Singapore differs according to the traffic volume, depending on the charging place and the time zone.

Table B.1 — Tariff of congestion charging in Singapore

ERP rate table for passenger cars, taxis and light goods vehicles (With effect from 20 February 2017 to 30 April 2017)					
	Orchard Cordon and Rest of CBD				
	Weekdays				
Time	Bugis-Marina Centre (9 gantries)	Shenton Way-Chinatown (11 gantries)	Orchard (9 gantries)	YMCA Gantry and Fort Canning Tunnel Gantry	Handy Road Gantry
GantryN0.	—	—	—	47,49	48
7.00am to 7.05am					
7.05am to 7.25am					
7.25am to 7.30am					
7.30am to 7.35am					
7.35am to 7.55am					
7.55am to 8.00am					
8.00am to 8.05am	$1,00	$1,00			$1,00
8.05am to 8.25am	$2,00	$2,00			$2,00
8.25am to 8.30am	$2,00	$2,00			$2,00
8.30am to 8.35am	$2,50	$2,50			$2,50
8.35am to 8.55am	$2,50	$2,50			$2,50
8.55am to 9.00am	$2,50	$2,50			$2,50
9.00am to 9.05am	$2,00	$2,00			$2,00
9.05am to 9.25am	$2,00	$2,00			$2,00
9.25am to 9.30am	$1,50	$1,50			$1,50
9.30am to 9.35am	$1,00	$1,00			$1,00
9.35am to 9.55am	$1,00	$1,00			$1,00
NOTE 1 Charge rate in the blank cells and the time between 10:30pm and 7:00am are $0,00.					
NOTE 2 Source: https://www.onemotoring.com.sg/content/onemotoring/en/on_the_roads/ERP_Rates.html					

Table B.1 *(continued)*

ERP rate table for passenger cars, taxis and light goods vehicles (With effect from 20 February 2017 to 30 April 2017)					
	Orchard Cordon and Rest of CBD				
	Weekdays				
Time	Bugis-Marina Centre (9 gantries)	Shenton Way-Chinatown (11 gantries)	Orchard (9 gantries)	YMCA Gantry and Fort Canning Tunnel Gantry	Handy Road Gantry
GantryN0.	—	—	—	47,49	48
9.55am to 10.00am	$0,50	$0,50			$0,50
10.00am to 10.05am					
10.05am to 10.25am					
10.25am to 10.30am					
10.30am to 10.35am					
10.35am to 10.55am					
10.55am to 11.00am					
11.00am to 11.05am					
11.05am to 11.25am					
11.25am to 11.30am					
11.30am to 11.35am					
11.35am to 11.55am					
11.55am to 12.00pm					
12.00pm to 12.05pm	$0,50	$0,50	$0,50	$0,50	$0,50
12.05pm to 12.25pm	$1,00	$1,00	$0,50	$0,50	$1,00
12.25pm to 12.30pm	$1,00	$1,00	$0,50	$0,50	$1,00
12.30pm to 12.35pm	$1,00	$1,00	$0,50	$0,50	$1,00
12.35pm to 12.5pm	$1,00	$1,00	$0,50	$0,50	$1,00
12.55pm to 1.00pm	$1,00	$1,00	$0,50	$0,50	$1,00
NOTE 1 Charge rate in the blank cells and the time between 10:30pm and 7:00am are $0,00.					
NOTE 2 Source: https://www.onemotoring.com.sg/content/onemotoring/en/on_the_roads/ERP_Rates.html					

Table B.1 *(continued)*

ERP rate table for passenger cars, taxis and light goods vehicles (With effect from 20 February 2017 to 30 April 2017)					
	Orchard Cordon and Rest of CBD				
	Weekdays				
Time	Bugis-Marina Centre (9 gantries)	Shenton Way-Chinatown (11 gantries)	Orchard (9 gantries)	YMCA Gantry and Fort Canning Tunnel Gantry	Handy Road Gantry
GantryN0.	—	—	—	47,49	48
1.00pm to 1.05pm	$1,00	$1,00	$0,50	$0,50	$1,00
1.05pm to 1.25pm	$1,00	$1,00	$0,50	$0,50	$1,00
1.25pm to 1.30pm	$1,00	$1,00	$0,50	$0,50	$1,00
1.30pm to 1.35pm	$1,00	$1,00	$0,50	$0,50	$1,00
1.35pm to 1.55pm	$1,00	$1,00	$0,50	$0,50	$1,00
1.55pm to 2.00pm	$1,00	$1,00	$0,50	$0,50	$1,00
2.00pm to 2.05pm	$1,50	$1,50	$0,50	$0,50	$1,50
2.05pm to 2.25pm	$2,00	$2,00	$0,50	$0,50	$2,00
2.25pm to 2.30pm	$2,00	$2,00	$0,50	$0,50	$2,00
2.30pm to 2.35pm	$2,00	$2,00	$0,50	$0,50	$2,00
2.35pm to 2.55pm	$2,00	$2,00	$0,50	$0,50	$2,00
2.55pm to 3.00pm	$1,50	$1,50	$0,50	$0,50	$1,50
3.00pm to 3.05pm	$1,00	$1,00	$0,50	$0,50	$1,00
3.05pm to 3.25pm	$1,00	$1,00	$0,50	$0,50	$1,00
3.25pm to 3.30pm	$1,00	$1,00	$0,50	$0,50	$1,00
3.30pm to 3.35pm	$1,00	$1,00	$0,50	$0,50	$1,00
3.35pm to 3.55pm	$1,00	$1,00	$0,50	$0,50	$1,00
3.55pm to 4.00pm	$1,00	$1,00	$0,50	$0,50	$1,00
4.00pm to 4.05pm	$1,00	$1,00	$0,50	$0,50	$1,00
NOTE 1 Charge rate in the blank cells and the time between 10:30pm and 7:00am are $0,00.					
NOTE 2 Source: https://www.onemotoring.com.sg/content/onemotoring/en/on_the_roads/ERP_Rates.html					

Table B.1 *(continued)*

ERP rate table for passenger cars, taxis and light goods vehicles (With effect from 20 February 2017 to 30 April 2017)					
	Orchard Cordon and Rest of CBD				
	Weekdays				
Time	Bugis-Marina Centre (9 gantries)	Shenton Way-Chinatown (11 gantries)	Orchard (9 gantries)	YMCA Gantry and Fort Canning Tunnel Gantry	Handy Road Gantry
GantryN0.	—	—	—	47,49	48
4.05pm to 4.25pm	$1,00	$1,00	$0,50	$0,50	$1,00
4.25pm to 4.30pm	$1,00	$1,00	$0,50	$0,50	$1,00
4.30pm to 4.35pm	$1,00	$1,00	$0,50	$0,50	$1,00
4.35pm to 4.55pm	$1,00	$1,00	$0,50	$0,50	$1,00
4.55pm to 5.00pm	$1,00	$1,00	$0,50	$0,50	$1,00
5.00pm to 5.05pm	$1,00	$1,00	$0,50	$0,50	$1,00
5.05pm to 5.25pm	$1,00	$1,00	$0,50	$0,50	$1,00
5.25pm to 5.30pm	$1,00	$1,00	$0,50	$0,50	$1,00
5.30pm to 5.35pm	$1,50	$1,50	$1,00	$0,50	$0,50
5.35pm to 5.55pm	$1,50	$1,50	$1,50	$0,50	$0,50
5.55pm to 6.00pm	$1,50	$1,50	$1,50	$0,50	$0,50
6.00pm to 6.05pm	$2,30	$2,30	$2,00	$0,50	$1,00
6.05pm to 6.25pm	$3,00	$3,00	$2,00	$0,50	$1,00
6.25pm to 6.30pm	$3,00	$2,50	$2,00	$0,50	$1,00
630pm to 6.35pm	$3,00	$2,00	$2,00	$0,50	$1,00
6.35pm to 6.55pm	$3,00	$2,00	$2,00	$0,50	$1,00
6.55pm to 7.00pm	$2,50	$1,50	$1,50	$0,50	$1,00
7.00pm to 7.05pm	$2,00	$1,00	$1,00	$1,00	$1,00
7.05pm to 7.25pm	$2,00	$1,00	$1,00	$1,00	$1,00
NOTE 1 Charge rate in the blank cells and the time between 10:30pm and 7:00am are $0,00.					
NOTE 2 Source: https://www.onemotoring.com.sg/content/onemotoring/en/on_the_roads/ERP_Rates.html					

Table B.1 *(continued)*

ERP rate table for passenger cars, taxis and light goods vehicles (With effect from 20 February 2017 to 30 April 2017)					
	Orchard Cordon and Rest of CBD				
	Weekdays				
Time	Bugis-Marina Centre (9 gantries)	Shenton Way-Chinatown (11 gantries)	Orchard (9 gantries)	YMCA Gantry and Fort Canning Tunnel Gantry	Handy Road Gantry
GantryN0.	—	—	—	47,49	48
7.25pm to 7.30pm	$2,00	$1,00	$1,00	$1,00	$1,00
7.30pm to 7.35pm	$2,00	$1,00	$1,00	$1,00	$1,00
7.35pm to 7.55pm	$2,00	$1,00	$1,00	$1,00	$1,00
7.55pm to 8.00pm	$1,00	$0,50	$0,50	$0,50	$0,50
8.00pm to 8.05pm					
8.05pm to 8.25pm					
8.25pm to 8.30pm					
8.30pm to 8.35pm					
8.35pm to 8.55pm					
8.55pm to 9.00pm					
9.00pm to 9.05pm					
9.05pm to 9.25pm					
9.25pm to 9.30pm					
9.30pm to 9.35pm					
9.35pm to 9.55pm					
9.55pm to 10.00pm					
10.00pm to 10.05pm					
10.05pm to 10.25pm					
10.25pm to 10.30pm					

NOTE 1 Charge rate in the blank cells and the time between 10:30pm and 7:00am are $0,00.

NOTE 2 Source: https://www.onemotoring.com.sg/content/onemotoring/en/on_the_roads/ERP_Rates.html

B.2 Tariff information provision

B.2.1 Urban congestion charging in Singapore

In Singapore's urban congestion charging, the charge amount varies depending on the location and time zone, so the existing time and charge amount by vehicle type are displayed on the gantry at each charging point.

Figure B.2 — Tariff on message sign (Congestion charging in Singapore)

B.2.2 Tariff and charge amount on OBE (HGV charging in Belgium)

In Belgium HGV charging, the existing charge amount and the cumulative charge amount of the day are displayed together with the travel distance on the display of the OBE.

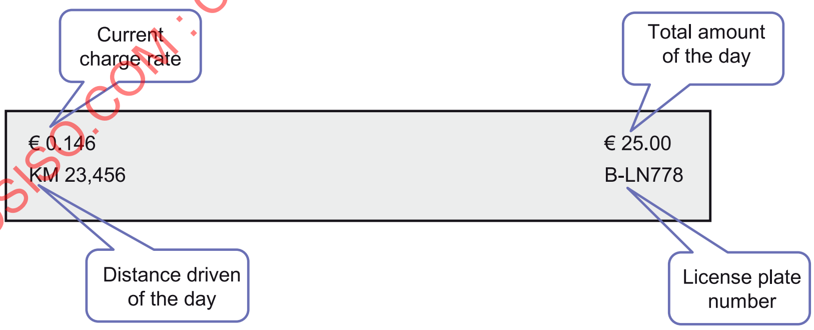

Figure B.3 — Tariff and charge amount on OBE (HGV charging in Belgium)

B.2.3 Express lane in USA

In the US HOV lane, charging amount for each destination is displayed on the roadside display board together with the guaranteed traveling time.

Figure B.4 — Tariff and driving time on message sigh (I-91 Express lane in USA)

Annex C
(informative)

Comparison of communication technologies

C.1 General

For EFC communication technology, short range communication and cellular communication are used, and comparison between existing communication technology and emerging communication technology is done respectively.

C.2 Short-range communication

Besides DSRC and WAVE developed as road-to-vehicle communication for ITS, RFID developed as a medium to replace the bar code of the supply chain and Bluetooth and ZigBee developed for inter-terminal communication are available for short-range communication. Since Bluetooth and ZigBee were originally developed for low-speed movement or fixed terminal-to-terminal communication, it is difficult to use for vehicles moving at high speed.