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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

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Foreword

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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.

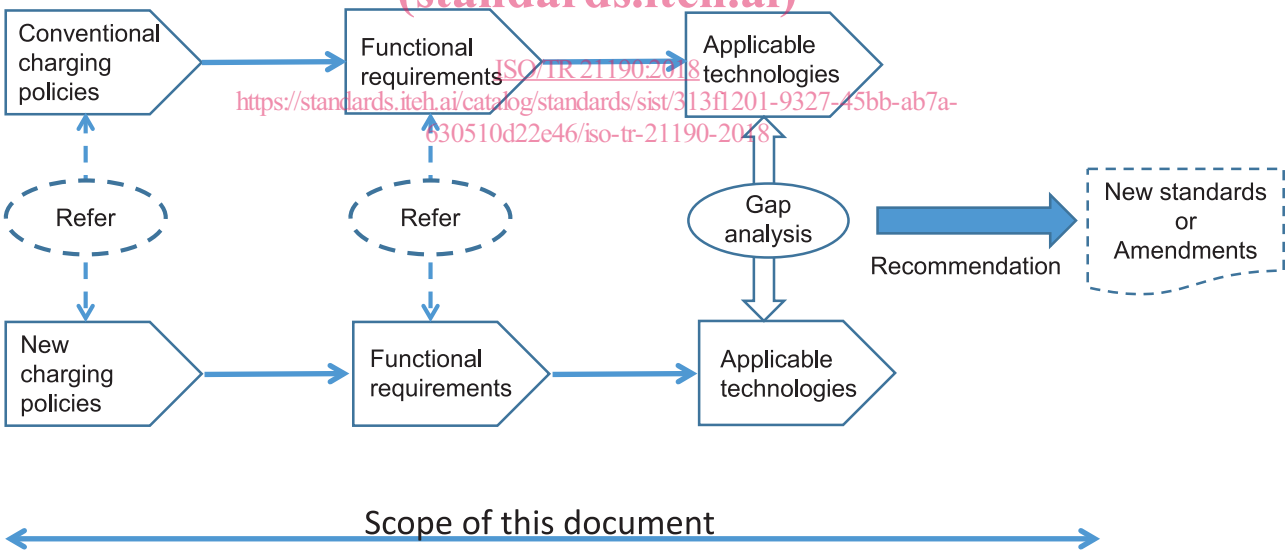

Figure 1 — Scope and process flow of this document

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 Corporation
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.

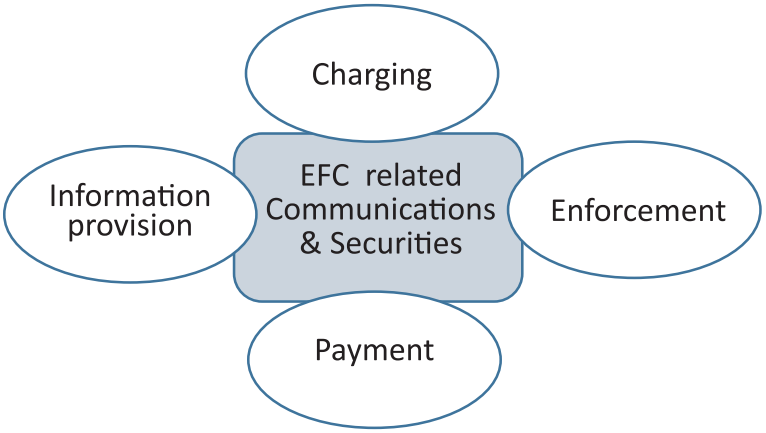

Figure 2 — EFC functional model

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.