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Electronic fee collection — Pre-study on the use of vehicle licence plate information and automatic number plate recognition (ANPR) technologies

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Electronic fee collection — Pre-study on the use of vehicle licence plate information and automatic number plate recognition (ANPR) technologies

Perception de télépéage — Pré-étude sur l'utilisation des informations de la plaque d'immatriculation du véhicule et la technologie de la lecture automatique des plaques minéralogiques (LAPI)

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Foreword

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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 278, *Intelligent transport systems,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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Introduction

This document endeavours to foster a common understanding in the context of electronic fee collection (EFC) systems of the use of vehicle licence plate information, and of automatic number plate recognition (ANPR) technologies.

This document notably seeks to advance the common understanding and definitions in the following areas:

— information associated with the licence plate number (LPN);

— information exchanges over open interfaces;

— outline of specification of exchanges between actors, notably the toll service provider (TSP), the toll charger (TC), vehicle registration authorities, etc;

— technologies regarding the ANPR.

The outcome is intended to contribute to more effective and efficient EFC schemes using vehicle LPN, obtained by means of ANPR technology and any associated information (including make and model) as a primary means to identify the user via the LPN, or a complementary means to augment the reliability and the robustness of their dedicated short-range communication (DSRC)-based or global navigation satellite system/cellular network) (GNSS/CN)-based systems (including degraded mode, trip reconstitution, etc).

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Electronic fee collection — Pre-study on the use of vehicle licence plate information and automatic number plate recognition (ANPR) technologies

1 Scope

This document provides an analysis of the use of licence plate number (LPN) information and automatic number plate recognition (ANPR) technologies in electronic fee collection (EFC), through the description of the legal, technical and functional contexts of LPN-based EFC. It also provides an associated gap analysis of the EFC standards to identify actions to support standardized use of the identified technologies, and a roadmap to address the identified gaps.

The gap analysis in this document is based on use cases, relevant regulations, standards and best practices in the field of EFC, based on the European electronic toll service (EETS)[27] model.

Examples of licence plate number (LPN)-based tolling schemes are given in Annex A.

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 terminology databases for use in standardization at the following addresses:

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

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

3.1
3 dimensional
3D
computer graphics that define an object by its width, length and depth

[SOURCE: ISO/TS 23541-1:2021, 3.1.1, modified — Note 1 to entry removed.]

3.2
automatic number plate recognition
technology to automatically read vehicle registration plates

Note 1 to entry: A vehicle registration plate typically contains the indicator or the code of the country that issued the vehicle registration plate.

Note 2 to entry: Optical character recognition techniques are typically part of the technology associated with automatic number plate recognition.

Note 3 to entry: Automatic licence plate recognition (ALPR) is a synonym to ANPR.

[SOURCE: ISO/TS 17573-2:2020, 3.18, modified — Note 3 to entry has been added.]

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3.3
artificial intelligence
<engineered system> set of methods or automated entities that together build, optimize and apply a model so that the system can, for a given set of predefined tasks, compute predictions, recommendations, or decisions

Note 1 to entry: AI systems are designed to operate with varying levels of automation.

Note 2 to entry: "Predictions" can refer to various kinds of data analysis or production (including translating text, creating synthetic images, or diagnosing a previous power failure). The term does not imply anteriority.

3.4
country code
identification of the issuing country of a licence plate, formatted in accordance with the United Nations Distinguishing Signs of vehicles in International traffic regulation

Note 1 to entry: In accordance with the United Nations Distinguishing Signs of vehicles in International traffic regulation,[33] the CC contains 1, 2 or 3 alphabetical characters.

Note 2 to entry: A "human-readable country code" is defined as a licence plate number where human inspection can determine the issuing country from syntax, font and other characteristics of licence plates.

3.5
error rate
ratio between the absolute error and the reference value of all transactions

3.6
false negative
incorrect reporting of a failure when in reality it is a pass

[SOURCE: ISO/IEC TR 29119-11:2020, 3.1.34, modified — Note 1 to entry and Example removed.]

3.7
false positive
incorrect reporting of a pass when in reality it is a failure

[SOURCE: ISO/IEC TR 29119-11:2020, 3.1.34, modified — Note 1 to entry and Example removed.]

3.8
false negative error rate
ratio between the false negatives and the reference value of all transactions

3.9
false positive error rate
ratio between the false positives and the reference value of all transactions

3.10
false recognizable error rate
ratio between the false recognizable transactions and the reference value of all processed transactions

3.11
infrared
optical radiation for which the wavelengths are longer than those for visible radiation

Note 1 to entry: For infrared radiation, the range between 780 nm and 1 mm is commonly subdivided

3.12
intelligent transport system
transport system in which advanced information, communication, sensor and control technologies, including the Internet, are applied to increase safety, sustainability, efficiency and comfort

[SOURCE: ISO/TR 17465-2:2015, 2.2]

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3.13
licence plate image
digital image on which a vehicle licence plate is visible

Note 1 to entry: A "human-readable licence plate image" is defined as a licence plate image with a human-readable licence plate number and country code.

3.14
licence plate number
number of the registration plate of a vehicle

3.15
manual number plate recognition
process of determining the licence plate number and country code by human inspection of a digital image

3.16
on-board unit
electronic unit on-board a vehicle for performing specific electronic fee collection (EFC) functions and for communication with external systems

[SOURCE: ISO/TS 17573-2:2020, 3.127]

3.17
optical character recognition
technique where characters are recognized and converted into binary code

[SOURCE: ISO 12651-1:2012, 4.100, modified — Note 1 to entry removed.]

3.18
payment means
means accepted by the service provider, that gives the user the right to use provided services

[SOURCE: ISO/TS 17573-2:2020, 3.134, modified — Example removed.]

319
toll domain statement
statement setting out the general conditions for European electronic toll service (EETS) providers for accessing a toll charger's toll domain.

Note 1 to entry: The definition is based on the EU directive 2019/520[27] on the recast of the European electronic toll service (cf. Article 6(2)).

3.20
user account
centrally or on-board stored transport-related service rights of the user in relation to a service provider

[SOURCE: ISO/TS 17573-2:2020, 3.228]

3.21
vehicle registration authority
authority responsible for the registration and maintenance of vehicle registers, including details of legal owners

4 Abbreviated terms

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

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AI	artificial intelligence
ALPR	automatic licence plate recognition
ANPR	automatic number plate recognition
BD	billing details
BO	back-office
CC	country code
CS	central system
OBE	on-board equipment
OBU	on-board unit
OCR	optical character recognition
EEA	European Economic Area
EETS	European electronic tolling service
EFC	electronic fee collection
EU	European Union
EUCARIS	European car and driving licence information system
HGV	heavy goods vehicle
IR	infrared
ITS	intelligent transport system
LP	licence plate
LPN	licence plate number
MNPR	manual number plate recognition
PAN	primary account number
RFID	radio frequency identification
SA	service area
SCC	specific commercial conditions
SU	service user
TC	toll charger
TI	technical interface
RSE	roadside equipment
TDS	toll domain statement
TSP	toll service provider
VIN	vehicle identification number
VRA	vehicle registration authority

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5 Legal context of LPN information

5.1 Regulated licence plate

The format of the number plate is usually defined in a jurisdiction by specific legislative acts, allowing LPN information to be used in many applications. The following is a non-exhaustive list of examples of such applications:

a) indication of registered vehicle;

b) indication of conformity to vehicle safety regulations at the time of registration;

c) certificate of usual vehicle parking location;

d) verification of vehicle insurance contract, or vehicle-related tax;

e) identification of vehicle usage types such as personal, commercial, rental, emergency, military;

f) toll collection;

g) enforcement, e,g. in case of traffic violation, car theft, crime.

These acts also specify the design and placement of the plate when mounted on the vehicle and the obligations of the vehicle owner. Each jurisdiction has its own specifications for the plate design as dictated by national priorities and use. As such, plate designs and placement typically differ between jurisdictions. ANPR systems need to be capable of dealing with all potential characteristics of the detected plates, such as:

— fixed position, angle, rotation, visible on vehicle;

— colour and painting and reflecting material of character and base plate;

— character alphabet;

— size and dimensional characteristics of characters (e.g. font width).

In principle, the TC can obtain the above information applicable to a given vehicle if the registration jurisdiction is known to it.

5.2 Physical characteristics of the licence plate

5.2.1 General

The LPN is a human- and machine-readable set of characters, represented in an image, which serves as a reference to the information of a licensed vehicle. As an example, in Europe the format for number plates follows the requirements listed in the Vienna Convention on Road Traffic.[23] Under the Vienna Convention, road vehicles carry their registration number on the front and back, even if legislation in the registration jurisdiction does not require a front vehicle registration plate on road vehicles.

The registration numbers:

— consist either of numerals or of numerals and letters;

— use capital Latin characters and Arabic numerals (can optionally be displayed in a different alphabet);

— carry (on the rear plate) a distinguishing sign of the registration jurisdiction.

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The requirement to display said distinguishing sign is mutually waived between some countries, for example (the list is not exhaustive):

— within the European Economic Area (EEA), for road vehicles with licence plates in the common European Union (EU) format (which satisfies the requirements of the Vienna Convention on road traffic, and which is also valid in those non-EU countries that signed the convention) issued in EU member states;

— between Canada, the United States and Mexico, where the province, state, or district of registration is usually embossed or surface-printed on the vehicle registration plate.

5.2.2 Licence plate characteristics in Europe

The common EU format for the licence plates for vehicles is defined as a blue section on the extreme left with the EU circle of stars and the country code. This was introduced by European Council Regulation (EC) No 2411/98.[24] According to Article 3 of this regulation, the distinguishing sign showing the State of registration placed at the extreme left of the registration plate is to be recognized in all Member States that require such information to be shown in vehicles registered in another Member State.

According to the Vienna Convention on Road Traffic,[23] vehicles in cross-border traffic are obliged to display a distinguishing sign of the country of registration on the rear of the vehicle (note that it is not common for ANPR-based systems to detect the country sign of the country of registration). This sign can either be placed separately from the registration plate or, pursuant to the amendments to the convention in 2006, can be incorporated into the vehicle registration plate. One of the main benefits of the convention for motorists is the obligation on signatory countries to recognize the legality of vehicles from other signatory countries. The Vienna Convention on Road Traffic lays out the following provisions concerning driving outside the country of registration:

— The physical requirements for the separate sign, defined in its Annex 3, state that the letters are to be written in black on a white background having the shape of an ellipse with the major axis horizontal. The distinguishing signs are not to be affixed in such a way that it could be confused with the registration number or impair its legibility.

— When the distinguishing sign is incorporated into the registration plate, it also appears on the front registration plate of the vehicle and can be supplemented with the flag or emblem of the national state, or the emblem of the regional economic integration organization to which the country belongs.

After approval of the EU directive 2019/520[27] on the recast of the European electronic toll service (EETS), the Commission implementing regulation (EU) 2020/204[29] was adopted. This regulation introduces ANPR among the EETS interfaces.

5.3 Licence plate properties

ISO 7591 specifies the performance of a retro-reflective registration plate. It specifies the minimum performance for a durability measurement of:

— photometric properties;

— uniformity of retro-reflection;

— colorimetric properties for day and night use;

— temperature resistance;

— adhesion to substrate;

— impact resistance;

— bending resistance;

— water resistance;

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— cleanability specifically when soiled by oil and graphite;

— resistance to fuel;

— resistance to saline mist.

The aim of ISO 7591 is to ensure plate readability by humans and machines for the lifespan of the plate. However, the duration of the readability is not specified. Common warrantees for retro-reflective sheeting, inks and foils are between 5 and 10 years. This value is important, since the average age of vehicles exceeds 10 years, which means that plates can degrade over time and become difficult to read.

NOTE 1 Some countries have adapted ISO 7591 into a national standard, e.g. DIN 74069.

Besides plate age, the following aspects, often induced by the vehicle owner/driver, also influence plate readability:

— delamination of the sheeting due to surface pits, cracks, and cuts, often the result of normal use due to stones and bumps;

— dirt, mud, and snow on the plates. Studies indicate that natural dirt formed on the top edges of embossed plates have an additional negative impact on read accuracy;

— paints, particularly infrared blocking plates, which obscure infrared reading of plates;

— plate-fastening screws and rivets which are placed strategically to trick the optical character recognition (OCR) system;

— plate covers, which act as filters, either by design or by aging;

— plate frames which encroach on the plate characters causing OCR systems to fail;

— other retro-reflective decals, marks and characters, which have been shown to reduce the ANPR ability to identify the plate on the vehicle;

— towbars, bike racks, cables, straps, etc., which obscure the line-of-sight;

— plates tilted to make it difficult for overhead cameras to read the plate. This typically happens on motorcycles.

Lastly, weather and lighting conditions play an important role in the read performance of a plate. For this reason, EFC operators often provide additional lights and weather protection to improve the ANPR.

With the widespread usage of traffic cameras, enforcement cameras, surveillance cameras and ANPR cameras, commercially available plate-detection-avoidance products are becoming increasingly available, such as plate-flippers, covering foils and sprays. Few countries have explicit regulations in place to deal with unreadable plates, plate tampering and aging.

Figure 1 shows the general process that results in the LPN from the image.

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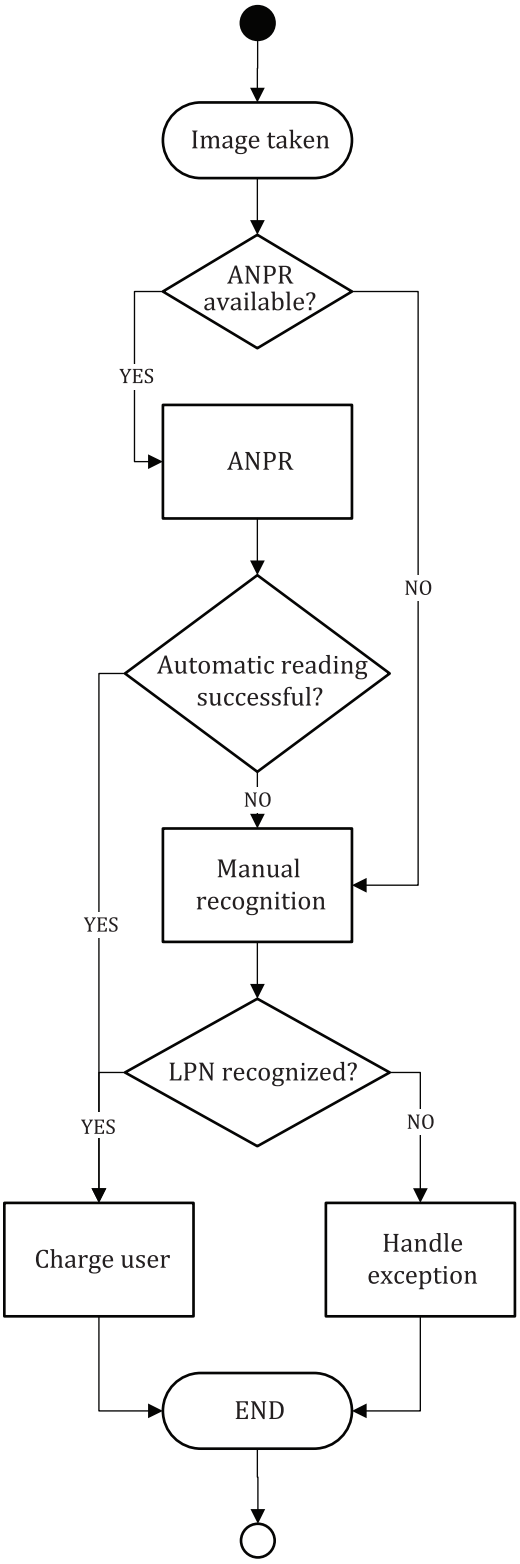

Figure 1 — From image to LPN

NOTE 2 The automatic recognition can occur at the roadside processing unit or/and in the back-office (BO). Usually, the roadside ANPR system employs fewer computational resources, for the sake of speed of elaboration, and typically provides lower accuracy and success rate than BO ANPR. An efficient ANPR process can involve both, in order to exploit the speed and real-time features of the roadside processing, and use BO processing as backup, whenever the previous fails.

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5.4 Illegal licence plates

The use of illegal plates is a globally increasing problem, particularly due to the increased use of ANPR and traffic surveillance cameras. As previously highlighted, cameras have difficulties authenticating a licence plate. However, especially when alternative routes to toll roads are available, rather than avoiding paying a toll, the intention of users of illegal plates is typically to try to avoid fines and penalties. Therefore, illegal plates are perceived to be of low importance for fee collection operators. Emerging tolling strategies and fee collection areas, like congestion zones and road-use charging, will increase the impact of illegal plates, especially for conformity checking of users through interrogation of on-board equipment (OBE) in autonomous tolling schemes. The ability to verify the authenticity of licence plates will increase in importance.

There are three types of illegal licence plate (LP):

— counterfeits plates: there exist many methods to manufacture plates outside of the regulated and controlled channels. As an example, the Internet offers many opportunities to obtain a counterfeit plate, often through a legitimate channel like offerings of custom/novelty plates. However, custom/novelty plate vendors operate in the open; as such, they are policed in many countries. Home-made plates are increasingly diffused, since the plate raw materials are easily available. Even the embossing of plates is not a hurdle due to the ease and cost efficiency of modern 3D printing. Embossing dies can easily be 3D-printed from a plate image. Counterfeit plates may be used for a long time. Such plates are only detected when the owner of the cloned plate reports it due to an unsought fee collection or transgression fine. Cases of innocent people implicated in crime due to counterfeit plates have been reported in the press;

— stolen plates: these are typically used in an opportunistic manner since stolen plates are reported when the vehicle owner detects the missing plates. The usefulness of a stolen plate is therefore limited in time;

— expired/terminated plates; these plates are typically plates salvaged from vehicles which are written-off due to a crash.

To reduce the chance of detection, perpetrators typically use an LPN of a legitimate vehicle of similar make, model and appearance. A strategy of using illegal plates in different jurisdictions than the original one also reduces the chance of detection. Typically, perpetrators will have several sets of plates which they will swap periodically.

Plate migration is the general term for when a legitimate LP is used on another vehicle. Plate migrations are executed by:

— a third party: effective measures are necessary for deterring, detecting and reporting such plate theft. Generally, the theft is detected at some point and is reported, allowing such plates (the plate number) to be listed, often to the inconvenience of the legitimate vehicle owner;

— by the vehicle owner/driver: typically, the LP of a low fee vehicle is used on a higher fee vehicle. For example, it has been reported that the plates of a pickup are being used on a truck. The ability to fit the plate to the correct class of vehicle will deter plate migration, though the class-of-vehicle information is available at the detection point.

6 LPN information for EFC

6.1 General principles

The licence plate number (LPN) is used as a primary vehicle identifier (in a recognition process that makes direct use of the LPN as recognition means) and a secondary vehicle identifier (in a process where another method, namely DSRC, is used as primary means of recognition) allowing the identification of the relevant user account or the owner of the vehicle. The LPN serves as a reference to the regulatory controlled licence information of a vehicle. This ensures the correct fee to be charged and, in case of non-payment, a fee recovery process to be acted.

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The regulatory licence information of the vehicle [e.g. vehicle identification number (VIN), make and model] which includes observable characteristics of the vehicle (e.g. shape, make, model, colour, size and number of axles), the usage of the vehicle (e.g. freight, emergency and public transport) and non-observable characteristics of the vehicle (e.g. type of power source, EuroClass, weight limits and ownership type – private vs business) can influence the fee and assist in detecting vehicle identity counterfeit LPs.

The user recognition and payment fulfilment can be pursued via several paths:

— directly: the user and the associated vehicle are contracted with the TC. Payment modality and fulfilment of amount due is directly with the user;

— via a third party: the user's vehicle is contracted with a payment fulfilment third party, typically a TSP, who cooperates with the TC and can be local or foreign to the TC's State;

— not contracted, but licensed: the user and associated vehicle is contracted with neither a TC nor a TSP. User information is obtained from the assumed VRA, which can be local or foreign. The relevant VRA is obtained by recognizing the country code;

— not contracted, with licensing information not available: the user information is not available through an assumed licensing department, the information is perhaps in doubt, or the use is challenged by an identified user. These cases are treated as enforcement processes depending on the relevant legal context, which can include specific interventions on the vehicle/user by the entities in charge.

6.2 Limitations of the LPN

The most relevant information on the identity of the licensing department of a vehicle's plate can be obtained from the state identifier on the LP or be derived from the LPN format. Both cases can be a challenge. First, the state identifier is not easily recognizable using current imaging methods. Then, many licensing departments use the same LPN formats. However, the plate country can be identified by using specific algorithms and/or by human review of the licence plate image.

6.3 LPN recognition process (ANPR)

The term ANPR is used for the automatic recognition of the vehicle number plate, i.e., localizing the plate in digital captured images of the front or rear of a vehicle and extracting the information available on the plate (digits, letters, specific characters).

The ANPR process starts with a camera which captures an image of the LP. The image is described in Figure 2; the blocks are explained below Figure 2 and 3.

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