

Annex B. Solution options

B.1 Introduction

This annex provides an overview of various potential operational and technological solutions for road pricing. Its content, intended audience and purpose can be summarised as follows:

- **Content** - this annex provides a high level overview of various potential operational and technological solutions for road pricing.
- **Target audience** - it is aimed at senior management (e.g. heads of service) and project managers within local authorities as well as technical scheme and system design teams working on business case development and scheme design.
- **Purpose** - the main purpose of Annex B is to inform the target audience about the operational and technological solutions available to them for a road pricing scheme, in order that these can be used in business case preparation and system design tasks.

A solution describes one way in which a user can interact with the road pricing scheme according to a set of scheme rules. It therefore includes both operational and technological aspects. It is envisaged that most schemes will adopt more than one solution in order to serve various scheme objectives or to meet the needs of different user classes. The solutions chosen are important because of the desire for consistency.

As noted above, this annex provides a high level description of solutions available for road pricing. Annex E then sets out more detailed technical guidance in relation to these solutions. Taken together, these annexes are intended to ensure that local authorities consider solutions that take account of key national issues surrounding those solutions.

It is important that in describing road pricing schemes, there is consistent use of terminology. Within this annex and elsewhere in these guidance annexes, the following key terms are used:

- **scheme** - a road pricing implementation that charges users for road use within defined geographic areas and within defined periods of time;
- **scheme owner** - the organisation legally entitled to implement a road pricing scheme - for example a local authority (or group of authorities);
- **solution** - one way in which a user can interact with a road pricing scheme;
- **user** - a person interacting in some way with a scheme. This may, for example, be the person who owns the vehicle, is the registered account holder or is driving on charged roads during a defined charging period;
- **service provider** - a provider of a service associated with road pricing that is defined by that provider and, typically, is offered under its own brand. For example, this might include sale, distribution and servicing of in-vehicle equipment (note: this is different from a contractor - see H for more details);
- **declare** - inform the scheme that a charge liability has been or will be incurred by a user; and
- **register** - the explicit initial provision of information in order to make use of a service or a particular solution in a certain way. This may be, for example, name/address type information for billing or payment details for direct debit payments.

More detailed definitions of all terms used in these annexes are included in Annex H.

Within their business case submissions, local authorities should:

- identify which solutions are expected to form part of their schemes (and, where relevant, the relative timing of introducing them);
- indicate which solutions they envisage being available to which user classes;
- provide details on the consequent traffic and (in particular) transaction volumes envisaged for each solution (including how this may evolve over time); and
- include the rationale and justification for these choices and projections.

B.2 Scheme characteristics

The starting point for the design of any road pricing scheme should be the scheme objectives, i.e. the targeted traffic reduction or congestion reduction impacts, which is covered separately in the Department's Transport Analysis Guidance (WebTAG).¹⁰

Having established the objectives and indications of the potential location(s) for charging, there are further design considerations local authorities need to take into account. Some of these considerations are described in the remainder of this section. They are based on the following general characteristics of a road pricing scheme:

B.2 Scheme characteristics

- the basis of the charge levied;
- who detects the charge liability;
- geographic structure; and
- event observation technology.

B.2.1 Basis of charge

A road user charge can be calculated in two basic ways:

- **event-based:** where the charge payable for a journey can be determined by one or more separate 'snapshot' observations of the vehicle, its location and the time. Typical examples are a vehicle passing a particular point (such as crossing a cordon) or a vehicle being observed within an area; or
- **rate-based:** where the charge payable for a journey is based on a parameter that accumulates over the journey. The charge is the increment of this parameter multiplied by the instantaneous charge rate. A typical example would be a charge that related to the distance travelled, hence the distance-based or more specifically **time, distance, place-based (TDP)** charge is the distance travelled multiplied by the charge rate applicable for each part of the journey at the time of travel.

An event-based solution will need to be included in every scheme (primarily to accommodate occasional users or visitors to a charged area). Local authorities may consider whether also to offer a TDP-based solution for some users.

B.2.2 Who detects the charge liability

Responsibility for detecting that a charge has been (or will be) incurred may lie with either the user or the scheme, as follows:

¹⁰ www.webtag.org.uk

- **user declaration:** The user is responsible for determining that a chargeable event has occurred (or will occur) and declaring it to the scheme. Separately, the scheme observes a proportion of chargeable events for compliance purposes. This is the main basis of the current London Congestion Charging scheme. User declaration solutions place the onus of declaration on the user. The user can take on the declaration responsibility themselves (referred to as personal declaration) or can potentially make use of third parties (service providers) to assist in determining that a charge liability has been or will be incurred and declaring it to the scheme; or
- **scheme detection:** The scheme itself is responsible for detecting when a vehicle has incurred a charge, which it can do making use of a number of potential technologies. The scheme is also responsible for instigating the collection of payment from the user, again with a range of potential mechanisms to achieve this. Separately, the scheme should seek to observe a (potentially significant) proportion of chargeable events for compliance purposes. This is the main basis for a number of tag-based schemes such as Singapore's electronic road pricing (ERP) scheme.

Local authorities will need to decide which option is appropriate for their circumstances and select solutions accordingly. It should be noted that each may be appropriate for different user and vehicle classes and therefore both may need to be included in a scheme design.

B.2.3 Geographic structure

Local authorities should set out the proposed geographic structure of their schemes within their business case submissions, specifically identifying the geography and locations covered, indicating whether the charge will be for cordons, points or areas, and highlighting any further rules that will impact the charge calculation.

In relation to **event-based** charging solutions, there are three main geographic structures:

- **area:** charge for driving within a given area. The London Congestion Charging scheme is a prominent example of an area charging scheme. The pertinent distinction between area and cordon is that an area charge applies for any travel within the area, irrespective of whether this involves crossing the boundary of the area;
- **cordon:** charge for crossing a closed cordon. The toll rings that are in operation in several Norwegian cities utilise a cordon charging structure, as did the Stockholm road pricing trial system that was operational for seven months during 2006. In contrast to area charges, a cordon-based scheme would not charge for travel purely within the boundary; and
- **point:** charge for driving past a particular point on the road network. Point charges may be used to address congestion issues on particular road segments or corridors and/or may supplement one or more charging cordons (as is the case with the Singapore ERP scheme).

There are a number of different ways in which solutions can be designed using these geographic structures. For example, cordon crossings can be one-way or two-way, can have rules concerning multiple crossings in a given time period (e.g. charging a vehicle for a maximum of, say, three crossings a day), or can determine a charge based on a combination of the entry and exit points (possibly with a time factor included). The same may be the case if a scheme includes multiple points. For area designs, again there may be several areas (contiguous or otherwise) that make up a scheme with the possibility of rules concerning use of multiple areas in a given time period. Further, a scheme may comprise a combination of any of these geographic structures.

For **TDP-based** charging, there are a number of ways in which the geographic structure can be set up. These are typically based on charging within a defined area (or on a particular road link or corridor). TDP-based charging is unlikely to be a major part of road pricing schemes that come into operation in the short term future.

B.2.4 Observation technology

For event-based road pricing, solutions need the ability to 'observe' chargeable events associated with individual vehicles for charging and/or compliance purposes. For TDP road pricing, solutions are likely to need the ability to capture 'spot' observations of an individual vehicle associated with a particular location

and time as part of a compliance regime. These observation activities can use various combinations of in-vehicle, roadside and remote communication technologies. Observations may be based on:

- **ANPR** (automatic number plate recognition): The scheme reads the vehicle number plate from roadside camera images to identify a vehicle and associate it with a chargeable event (or for compliance comparison with data on a distance-based charged journey);
- **charging tag**: The vehicle carries a tag¹¹ that the scheme can read electronically to identify the tag which can then be associated with a chargeable event and linked to a charge payer account. The tag may also provide the ability to confirm the transaction associated with the chargeable event to the driver (e.g. by beeping or flashing); and
- **GNSS** (global navigation satellite system): An onboard unit (OBU) calculates the location of the vehicle at a particular time using (potentially in combination with other sensors) a set of signals from GPS (global positioning system) or potentially Galileo satellites. This data may be used to determine what charges are due either by calculation within the OBU or by uploading the data to an off-board facility for this data processing to be undertaken.

This is not intended as an exhaustive list, nor is it intended to rule out the potential for new or innovative technologies (for example, GSM cell positioning) to contribute to road pricing solutions. Rather it gives an indication of the technologies that appear most likely to form the basis of initial solutions. The list is compatible with the European interoperability Directive on electronic road charging (2004/52), as described in Annex C.

Within their business case submissions local authorities should identify which technologies they envisage including and/or allowing for in their schemes. This will logically follow from the selection of solutions described later in this annex.

B.3 Overview of solution options

Combining the different characteristics described above clearly leads to a large number of potential solutions. Analysis of these characteristics based on logical and practical constraints has identified five possible solutions (or solution groups) that might offer a useful starting point for those engaged in scheme design.

Based on the relative maturity and initial estimates of the affordability of the technologies involved, three solutions are viewed as most likely to be viable in the short term:

- a. Personal declaration, event-based charging;
- b. Scheme detection (ANPR), event-based charging; and
- c. Scheme detection (tag & beacon), event-based charging.

In addition, local authorities can consider solutions in the following groups, both of which rely on some degree of further development before implementation:

- d. Assisted declaration, event-based charging (with a service provider assisting the user in some way in declaring); and
- e. TDP-based charging (charging by time, distance and place).

The figure below summarises the logical derivation of the three solutions and two solution groups.

¹¹ In principle, electronic vehicle identification (EVI) tags for general vehicle identification purposes could be used to form the basis of a road pricing solution if they meet the requirements set out in EC Directive 2004/52 on interoperability of electronic charging systems (see Annex C), or if they are used solely to identify vehicles (for example for enforcement purposes), not to collect charges.

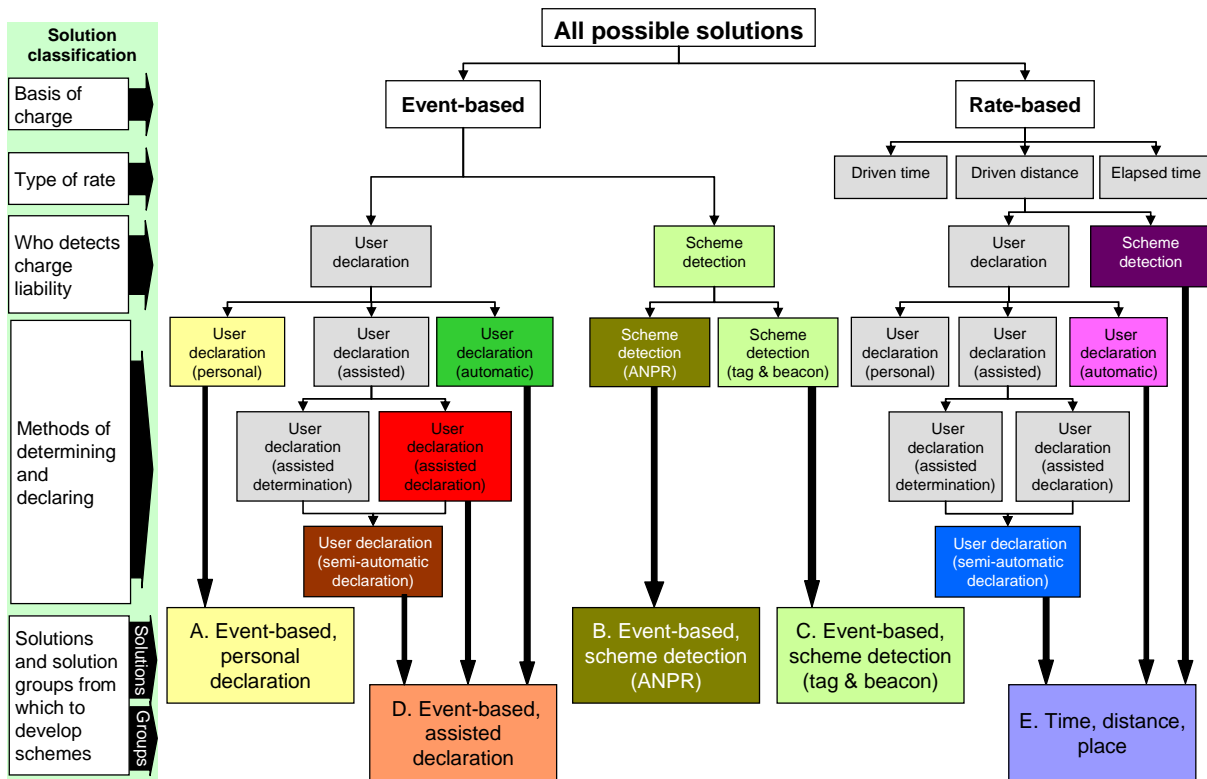


Figure B.1 Derivation of solutions and solution groups for consideration in scheme designs

An overview of each of these solutions / solution groups is given in the following sub-sections, while further guidance and detail on key issues associated with each is included in Annex E. If local authorities feel that other solutions would be feasible and better fit their needs, they are encouraged to discuss them with the Department in the first instance.

A scheme may incorporate more than one solution in order to meet the needs and constraints of different users. Indeed, it is desirable that all but the smallest scale road pricing schemes do incorporate more than one solution in order to maximise cost-effectiveness and meet a range of user needs.

Local authorities should give consideration to the charges levied in each solution. Within certain fairness constraints, there is scope for a scheme to charge a different amount depending on the solution a user chooses to use, reflecting differences in operating costs among the solutions. This may provide a tool that can incentivise users into certain solutions.

Personal declaration, event-based charging (Solution A in the list above) is the only solution that can readily accommodate occasional users without them having to take any action prior to using the scheme - i.e. they can 'just turn up'. Given that schemes will need to provide for this case, this personal declaration solution must be a part of all schemes. However, in some circumstances this may prove to be a more costly way of dealing with all charging events compared with some other possible solutions.

Local authorities should therefore consider including additional solutions within a scheme and whether they should incentivise users to use these additional solutions instead of personal declaration. Local authorities should include within their scheme design whatever other solutions are relevant for the particular local circumstances and define which solutions are available, compulsory or prohibited for different types of scheme user.

B.4 Personal declaration, event-based charging solution

B.4.1 Solution overview

In this solution, users are responsible for determining that they will incur (or have recently incurred) an event-based charge liability and declaring it to the scheme owner. Such an event may include, for example,

entering a charged area, crossing a cordon, or travelling within a charged area (depending on how the geographic charging structure of the scheme is defined). Compliance is maximised through detection checks using, for example, mobile or fixed cameras with ANPR technology.

The current London Congestion Charging scheme uses this type of solution for most general users. Here, users who choose to drive their vehicle within the charged area within the prescribed hours have to declare this to Transport for London (beforehand or within a certain time limit after doing so) and pay the appropriate charge for their vehicle. There is a range of channels for declaring and paying the charge including internet, telephone, retailer terminals, and SMS text messaging.

Particular features of a personal declaration, event-based solution are that:

- users do not need to have any onboard equipment in their vehicles - the vehicle registration mark (VRM) serves as the identifier to link the user with declaration and payment, and is used by the scheme owner for compliance check purposes; and
- users do not need to pre-register, set up an account or subscribe to a service - it is the only one of the solutions set out here that allows users to 'just turn up' and use the scheme.

B.4.2 Potential application

The concept of this solution is simple and therefore can be readily communicated to the public. The declaration concept is best suited to simple area-based schemes since it involves users declaring their use irrespective of which part of an area they have driven in. Whereas if the scheme is responsible for detection it requires all vehicles driven anywhere in the area to be detected by the scheme, which in many cases is unlikely to be practical. It can readily be used for cordon schemes as well, subject to the need for the overall scheme being sufficiently simple for it to be understood by users.

Given the need to explain the scheme rules to users, this solution is not so well suited to more complex scheme structures such as those that have a number of charging zones or complex charge tariffs.

One of the advantages of this solution is that it can cater for users who have not pre-registered and have no additional equipment in their vehicles. It is therefore particularly suited to accommodating occasional users. Similarly it provides a potentially attractive solution for accommodating foreign registered vehicles.

B.5 Scheme detection (ANPR), event-based charging solution

B.5.1 Solution overview

In this solution, the scheme is responsible for determining when a chargeable event has occurred by detecting vehicle passages during the prescribed charging periods. As with the personal declaration solution, such an event may include entering a charged area, crossing a cordon or travelling within a charged area. Failure of the scheme to detect a passage when a user is compliant with the scheme rules results in no charge being levied for that event.

This solution uses camera and ANPR technology to determine when a chargeable event has occurred and to initiate the charging process. Successfully levying charges on vehicles is therefore highly dependent on the ANPR technology achieving a very high read accuracy rate in order to minimise the amount of manual analysis of number-plate images.

The London Congestion Charging fleet automated scheme (for organisations with a fleet of at least 10 vehicles) uses this solution. The 407 Express Toll Route (ETR) in Ontario, Canada is another example where this solution has been incorporated, although in that case users are strongly incentivised to use the main tag-based solution instead by including a premium on all toll passages by drivers who choose to use the camera and ANPR detection solution.

As with personal declaration, scheme detection with ANPR does not require any onboard equipment to be fitted to vehicles. Under this solution, users within the defined user classes for whom this solution is available would need to register (potentially with a pre-paid or post-paid account) providing information that includes their VRMs.

B.5.2 Potential application

This solution is considered applicable as an option for certain user classes (e.g. certain vehicle fleets, as is the case in London), where a scheme owner may decide that the advantages in terms of user convenience and administrative simplicity and efficiency for certain users may outweigh any potential revenue loss and/or extra administrative cost when compared with personal declaration. The potential revenue loss comes from the need for the scheme to detect every vehicle - if it cannot read a number plate, the user is not charged. The extra administrative cost comes from needing to capture and analyse a very high percentage of number plate images to maintain revenue. It therefore may be less suitable for use with large numbers of individual vehicles.

This is a viable solution for cordon scheme designs where detection equipment can be placed on all entry/exit points. Because of the nature of scheme detection, it is a possible solution for an area-based scheme design, but would require careful consideration of how to detect use within an area. There are ways of making this work, for example with ANPR cameras at key locations within an area along with mobile detection units, but these need to be considered in the context of the local scheme design.

As with the scheme detection (tag) solution (see following sub-section), revenues collected are dependent on the roadside charging equipment functioning correctly. As such, any downtime for roadside charging equipment may result in a direct loss of revenue, although multiple monitoring sites may mitigate this to some extent.

B.6 Scheme detection (tag), event-based charging solution

B.6.1 Solution overview

In this solution the scheme is responsible for determining when a chargeable event has occurred by detecting vehicle passages during the prescribed charging periods. Whereas the previous solution used cameras and ANPR for this activity, in this solution the main event observation technology that initiates the charging process uses in-vehicle tags read by roadside beacons. These use short range (5.8 GHz microwave) communications as a vehicle passes a charging point or crosses a cordon to initiate a charge being levied. Compliance checks use sensors that detect vehicles linked to cameras and ANPR technology, with the roadside technology linking detected vehicle passages with tag-beacon data transactions and with camera images.

The scheme detection (tag) solution requires users to have a tag fitted to their vehicles. This is not envisaged as a complex fitting exercise, as is evidenced by existing schemes that use tag and beacon technology. Indeed, there is considerable experience with using tag and beacon technology as the basis for initiating a charging process (particularly compared with using ANPR in this role) and a corresponding track record of high tag read accuracy results. Prominent examples where this solution has been implemented include:

- the Singapore electronic road pricing scheme - this has been operational since 1998 and is based around mandatory use of relatively sophisticated tags incorporating smart cards;
- Stockholm - Vägverket (the Swedish Road Administration) with the City of Stockholm operated a road pricing scheme on a trial basis for the first seven months of 2006, which included a tag-based scheme detection solution (as well as other solutions); and
- the Trondheim Toll Ring - the Norwegian city of Trondheim operated a toll scheme from 1991 that used a tag-based scheme detection solution.

B.6.2 Potential application

This solution is particularly suited to cordon- and point-based charging schemes, and can support a more complex scheme design than is the case for personal declaration solutions. This is because it is the scheme rather than the user that is responsible for determining the charge liability. This could mean dividing a scheme into more geographic zones or including more charge levels by time of day or user class.

In this solution interoperability issues are more prominent than in the personal declaration and scheme detection (ANPR) solutions. As well as needing to be compliant with European standards (see Annex C),

these solutions should operate in such a way that ensures users only require one tag and can use a single account/registration across all UK schemes that use this solution.

This solution requires in-vehicle equipment - a dedicated short range communication (DSRC) tag. Consequently, scheme owners need to consider how tags are distributed (where and by whom) and linked to users. Further practical issues such as tag battery life need to be taken into account. Revenues collected by this solution are dependent on the roadside charging equipment functioning correctly. As such, any downtime for this equipment may result in a loss of revenue, although multiple monitoring sites may mitigate this to some extent.

B.7 Assisted declaration, event-based charging solutions

B.7.1 Solution overview

This solution group is similar in concept to personal declaration. However, under this solution group, there are third party service providers assisting the user in determining and declaring charge liability to the scheme.

Three main solution types are envisaged in this context where service providers can play a role in a scheme that is already offering a personal declaration solution. These are:

- **assisted declaration** - the service provider offers a means (e.g. a single phone number or web address) for the user to declare and pay appropriate charges with any scheme. The market for such a service may become more attractive once a number of schemes are in operation around the country;
- **semi-automatic declaration** - the service provider offers a means (for example, through an in-vehicle satellite navigation system) for automatically determining when a charge liability has been incurred and informing the user that a declaration should be made. The user then considers the information provided before authorising the service provider to declare and pay appropriate charges to the scheme; and
- **automatic declaration** - this is similar in concept to a semi-automatic declaration service, except that declaration by the service provider automatically follows determination of a charge liability without the intervening step of user authorisation. This enables users to 'fit and forget' about charge liabilities once they have subscribed to the service, subject to certain conditions a service provider may impose such as ensuring the in-vehicle equipment is in working order.

B.7.2 Potential application

This solution group is a logical extension to personal declaration. The difference is that it provides the opportunity for service providers to add road pricing onto an existing commercial offering. For example, navigation or other vehicle tracking service providers may be able to use their vehicle location capability to prompt the user to declare. They may take this a stage further and declare on the user's behalf. As such, versions of this solution group may provide a 'staging post' to further involvement of service providers in road pricing charging by time, distance and place (TDP).

As with personal declaration, this solution group can work effectively for both areas and cordons. Given the potential for service providers to automate some of the functions that a user would otherwise have to take on, this solution group lends itself to a slightly more complex scheme design and scheme rules than personal declaration.

If versions of this solution group are adopted, appropriate opportunities need to be built into the scheme design for service providers to interact with the scheme on behalf of users who subscribe to their services. The contractual arrangement between the scheme and the service provider is a design issue. Local authorities adopting this solution as part of their scheme therefore need to consider issues such as:

- whether there should be a 'wholesale' rate for service providers on road charges they collect on behalf of the scheme to incentivise their participation;
- how any enforcement action is targeted (e.g. whether the service provider or the individual user should be the first and/or ultimate point-of-call in the event of enforcement action); and

- whether service providers should be allowed a different margin for errors in declaring usage than individual users.

B.8 Time, distance, place-based charging solutions

B.8.1 Solution overview

This solution group encompasses a range of possibilities concerning charging based on time, distance and place (TDP), where the charge is determined from the time of travel, the distance travelled and the place of travel. Charging according to distance travelled generally requires an onboard unit (OBU) with a vehicle positioning capability (e.g. through GNSS or potentially other technologies¹²).

In the context of early TIF schemes, if TDP-based charging is offered it would probably be as an option for some users as an alternative to paying on an event basis. Within scheme design and business case development, consideration of including a TDP-based charging solution as an option for some users is encouraged.

B.8.2 Potential application

TDP-based charging has attractions as a potentially powerful demand management tool. From a system perspective, it provides a very flexible solution since the scheme boundaries exist in software rather than physically on the ground. Hence, if traffic patterns change, the systems aspects of scheme boundaries can more readily be altered to accommodate the change. Other changes would still be required to achieve this, however, such as to road signs. Further, if TDP is part of an otherwise event-based scheme, then any boundary change would need to cover the other solutions included within the scheme. At present TDP-based road user charging is the least proven of the solutions available to schemes.

TDP-based charging could form part of solutions based on scheme detection or user declaration. With scheme detection, the scheme operator is responsible for issuing, distributing and managing appropriate OBUs (possibly through a third party contract agreement). The scheme (of which the OBUs would be a key part) is then responsible for detecting and communicating the charge liability and for levying the appropriate charges.

With a user declaration-based TDP charging solution, users would generally need an appropriate OBU that could determine their charge liability. This could be an OBU of an approved standard provided by a service provider as part of a subscription service. Declaration and payment of the charge could then be 'semi-automatic' (with an opportunity for the user to review the calculated charge liability before it is declared to the scheme - as is the case for some users of the Swiss lorry charging scheme) or more probably fully automatic through data transmission from the OBU.

¹² Tag and beacon technology could theoretically be used to detect vehicles travelling on a defined road segment as a proxy for distance. However, this would be difficult and expensive to apply given the scale of roadside infrastructure it would require, particularly in a complex urban context.