TRANSPORT RESEARCH LABORATORY

Review of tolling and communications aspects of the US National Architecture

Prepared for Tolling and Private Finance Division, Department of the Environment, Transport and the Regions

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Executive Summary

TRL has undertaken a review of tolling and DSRC communication aspects of the US National Architecture (NA) on behalf of Department of Transport (now Department of the Environment, Transport and the Regions) Tolling & Private Finance Division (TPF2).

The primary source of material for this investigation was the US National Architecture documents. In reality, these documents are a *Report* on the National Architecture project. The documents contain information about architecture, but also proposals and discussions about communication choices, economics of operation, required standards and very detailed information, in some areas, about data structures to be communicated across interfaces.

In the course of the review, TRL accessed documents from a variety of other sources including periodicals, Internet sites and Standards bodies.

It became apparent that the American and European perspectives differ. The human geography of the US has greatly affected the choices made within the NA. For example, population centres are, on the whole, separated by comparatively long distances and this affects the economics of beacon installations.

It is concluded that the NA has made specific choices in the areas of tolling and DSRC which may not be appropriate for the UK and Europe. This includes some of the lower-level data structures which define information flows across interfaces, and these data structures do not appear flexible enough to meet future application needs.

Recommendations are made concerning tolling and more general DSRC information:

It is recommended that information services based on DSRC beacons continue to be developed and trialed. The emphasis should be on networked beacons as part of a national infrastructure. The commitment to a national tolling infrastructure based on DSRC could provide a substantial boost to the provision of ‘value added’ services over DSRC.

It is also recommended that the UK continues with Europe to develop the CEN approach to harmonisation of fee collection transactions. This would, for example, allow different countries to continue to use different vehicle classification systems and still be interoperable.

1 Introduction

1.1 Background

A system architecture is a description of how elements or sub-systems work together to perform the actual function of a system. It describes the functions of the individual sub-systems and how they interact, by defining the type and characteristics of information which is exchanged.

On the 8-9 May 1996, TRL and ITS-Focus organised a workshop to discuss System Architecture following the completion of a 3-year US DOT project to define and report on a proposed National Architecture.

At the end of 1996, ITS-Focus convened a Task-Force to report on the relevance of the US architecture to the UK. This report is an expanded version of the contribution made by TRL to that Task Force, and concentrates on the areas of Dedicated Short Range Communications (DSRC) and Electronic Fee Collection.

1.2 Introduction to the US documentation

The source material for this investigation included about 3,000 pages of documentation arising from the US National Architecture work performed by the Rockwell, JPL and Loral organisations. In reality, these documents are a *Report* on the National Architecture project. The documents contain information about architecture, but also proposals and discussions about communication choices, economics of operation, required standards and very detailed information, in some areas, about data structures to be communicated across interfaces.

It must be noted that since the US work was undertaken during 1994-96, it can be expected that at least some of the thinking is two years out of date! In the rapidly moving world of Intelligent Transport Systems, ideas can be overtaken by technology or by the work and success of other countries, organisations or standards.

Therefore, in seeking to understand the architecture and associated documentation, and to assess the relevance to the UK situation, there have been difficulties. The summaries, conclusions and recommendations provided in this report should be regarded as an interpretation of the US position which may need to be verified in detail by further reference to the documentation and by consulting more current sources.

2 Documents reviewed

In the course of the review TRL has accessed documents from a variety of sources. These sources have included periodicals and Internet sites which contain related information. A list of related Internet sites are tabulated below.

http://www.comnets.rwth-aachen.de/guest/ftp-wg9/	www site containing ISO TC278 WG9 home page
ftp://www.comnets.rwth-aachen.de/guest/ftp-wg9/	ftp site containing ISO TC278 WG9 documents
http://www.iso.ch/meme/T204.html	TC204 page of the ISO
http://www.rockwell.com/itsarch/	ITS architecture information on Rockwell's www site
http://www.itsa.org/	ITS home page
http://www.open.gov.uk/dot/dothome.htm	UK DOT home page
http://www.dot.gov/dotinfo/fhwa/its/	DOT information on DSRC

However, the primary source of information comprised the ITS Architecture documentation. The main reports (US DOT FHA 1996) which were of use to the reviewers are described in the following paragraphs:

ITS Architecture: Executive Summary

The ITS Architecture: Executive Summary provides a broad-brush description of the ITS Architecture component documents, and identifies which guidelines are of most use to the different actors who are interested in the National Architecture. The summary also provides an overview of the complete architecture and is a useful starting point for the casual reader.

ITS Architecture: Mission Definition

The Mission Definition contains the system level concepts and requirements that document the fundamental needs to be fulfilled by a successful ITS architecture. It provides a representation of the system that is useful for conveying the ideas for future improved transportation systems to the general public.

ITS Architecture: Theory of Operations

This document provides a simple guide to how the architecture supports ITS implementations. It contains information that explains the operational concepts the architecture uses to implement user services. Advantages and disadvantages of alternative operational concepts are also presented.

ITS Architecture: User Services Summary

The National ITS programme is focussed on the development of a collection of inter-related services. In the User Services Summary the twenty nine user services, which have been identified as part of the national planning process, are defined.

ITS Architecture: Standards Development plan

The Standards Development Plan presents the steps that need to be taken in order to produce a collection of interface standards. The document leads a standards development organisation through the architecture documents. It also defines those standards that require national interoperability for nationwide deployment of ITS. For each deployment feature (e.g. DSRC), either a set of existing standards activities are identified, or new standards work is recommended.

Standards Development Plan, Standards Requirement Package 1: Dedicated Short Range Communications

For Dedicated Short Range Communication a set of existing standards activities is identified. The document identifies the transaction sets used in the various DSRC interfaces and describes the logical architecture flows.

3 Overview of the US National Architecture

3.1 Introduction

The National ITS Architecture provides a common structure for the design of intelligent transportation systems. It defines the framework around which multiple design approaches can be developed and tailored to meet the individual needs of the user, while maintaining the benefits of a common architecture. The architecture defines the functions (e.g. gathering traffic information or requesting a route) that must be performed to implement a given user service, the physical entities or sub-systems where these functions reside (e.g. the roadside or the vehicle), the interfaces/information flows between the physical sub-systems, and the communication requirements for the information flows (e.g. wireline or wireless).

In addition, the documentation identifies and specifies the requirements for the standards needed to support national and regional interoperability, as well as product standards needed to support economy of scale considerations in deployment.

3.2 National Architecture sub-systems

The NA comprises four distinct sub-systems. If communication is possible between two sub-systems then this is represented by a double-headed arrow (see Figure 1). Naturally, the methods of communication differ in their suitability for the various sub-system interfaces. For example, the NA indicates that wireline communications should be used between the Centre Sub-systems and Roadside Sub-systems.

It is expected that Vehicle Sub-systems and Roadside Sub-systems will communicate using Short Range Wireless Communications, in particular Dedicated Short Range Communication (DSRC). Thus, it is likely that any tolling applications will rely on DSRC for vehicle to roadside communications. However, Centre to Vehicle communication is also supported (e.g. RDS broadcasts and cellular radio). One area of contention, as will be described below, is the choice of Centre-Vehicle communications rather than Centre-Roadside-Vehicle communications for a particular function.

Roadside sub-systems

Roadside sub-systems include functions that require convenient access to a roadside location for the deployment of sensors, signals, programmable signs, or other interfaces with travellers and vehicles of all types. The four Roadside Sub-systems are described below:

Roadway	Provides traffic management surveillance, signals, and signage for traveller information.
Toll collection	Interacts with vehicle toll tags to collect tolls and identify violators.
Parking management	Collects parking fees and manages parking lot occupancy/availability.
Commercial vehicle check	Collects credential and safety data from vehicle tags, determines conformance to requirements, posts results to the driver (and in some safety exception cases, the carrier), and records the results for the Commercial Vehicle Administration Sub-system.

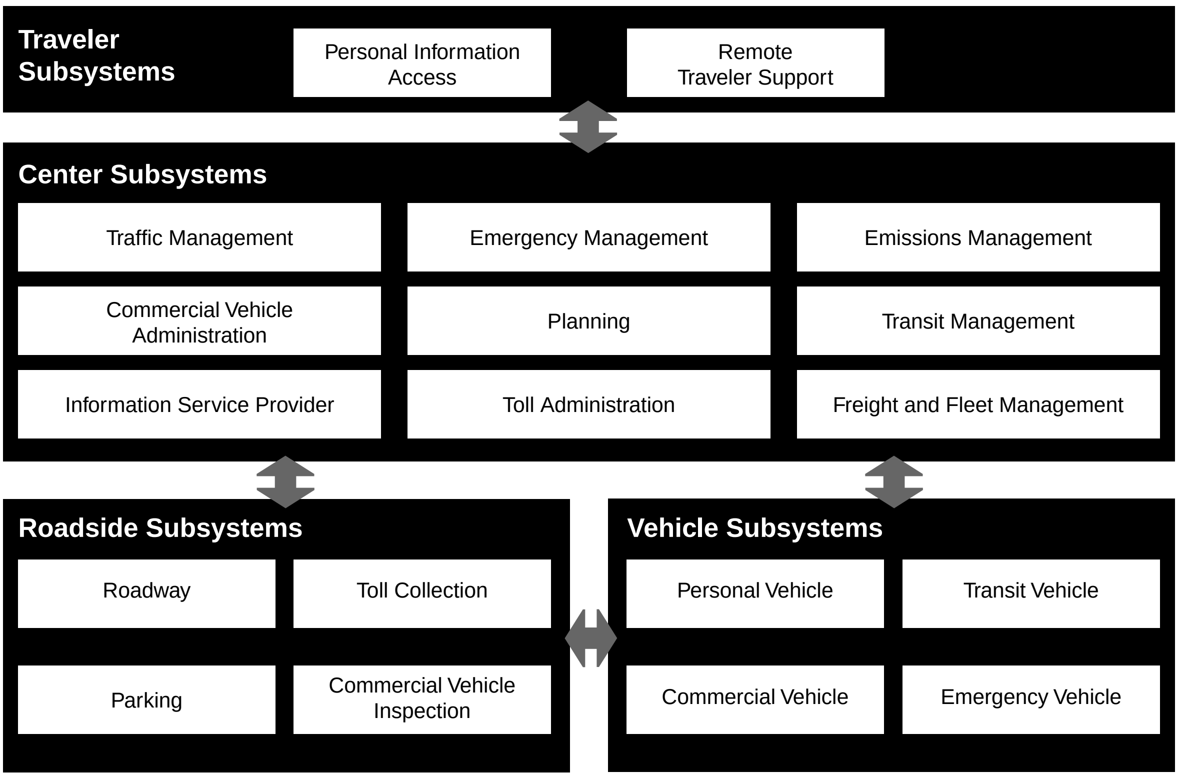

Figure 1 Architecture systems and sub-systems (reproduced from ITS Architecture Executive Summary)

Vehicle sub-systems

These sub-systems are installed in a vehicle. The four Vehicle Sub-systems are described below:

Vehicle	Functions that may be common across all vehicle types are located here (e.g. navigation, tolls, etc.) so that specific vehicle deployments may include aggregations of this sub-system with one of the other three specialized vehicle sub-systems types. The Vehicle Sub-system includes the user services of the Advanced Vehicle Control and Safety Systems user services bundle.
Transit vehicle	Provides operational data to the Transit Management Centre, receives transit network status, provides en route traveller information to travellers, and provides passenger and driver security functions.
Commercial vehicle	Stores safety data, identification numbers (driver, vehicle, and carrier), last check event data, and supports in-vehicle signage for driver pass/pull-in messages.
Emergency vehicle	Provides vehicle and incident status to the Emergency Management Sub-system.

3.3 Communications

The National ITS Architecture provides a framework which is intended to enable the development and effective implementation of the broad range of ITS user services. Its development has focussed upon using existing and emerging transportation and communication infrastructures in its design. There are multiple communications options available to the system designer. However, the choice between the various options is dependent upon an, arguably, restrictive system architecture as well as local, regional, and national needs.

The architecture identifies four communication media types to support the communications requirements between the nineteen sub-systems. They are *wireline* (fixed-to-fixed), *wide area wireless* (fixed-to-mobile), *dedicated short range communications* (fixed-to-mobile), and *vehicle-to-vehicle* (mobile-to-mobile). A top level sub-systems interconnect diagram that identifies the communications media interfaces between the architecture's nineteen sub-systems is shown in Figure 2.

Within the architecture, two distinct categories of wireless communications (based on range and area of coverage) have been identified. Wide area wireless (fixed-to-mobile) communications are suited for services and applications where information is disseminated to users who are not located near the source of transmission and who require seamless coverage. Wide area wireless communications are further differentiated based on whether they are one-way or two-way. An example of a one-way, broadcast transmission is a traffic report using FM radio. A mobile traveller who requests and receives current traffic information from an Information Service Provider (ISP), is an example of the use of two-way communications.

The second category, short range wireless, is concerned with information transfer that is of more localised interest. There are two types of short range wireless communications identified by the architecture. They are Vehicle-to-Vehicle and Dedicated Short Range Communications (DSRC). Vehicle-to-Vehicle (mobile-to-mobile) short range wireless communications are required to support the Automated Highway System (AHS), and most likely, intersection collision avoidance implementations. DSRC are discussed in the next section.

3.4 Dedicated short range communication

In the National Architecture, DSRC provides the set of wireless interfaces between roadside devices and the vehicle sub-systems. These interfaces are dedicated short range links that most commonly utilise radio frequency or infrared communications technology. The DSRC links only support electronic tolling and commercial vehicle electronic clearance in current deployments, and the architecture 'envisions' that parking management, AHS, and in-vehicle signing could also utilise DSRC in the future.

According to the NA documentation, appropriate applications for DSRC (fixed-to-mobile) include toll collection, parking fee collection, roadside safety inspections, credential checks, in-vehicle signing, intersection collision avoidance, and selected Automated Highway System (AHS) communications (e.g., safety checks, access authorization, and system status updates). Radio frequency (RF) and Infrared (IR) short range wireless beacon/tag communications have been assessed in the NA for their DSRC requirement. Key issues identified for further analysis and study are the required coverage of beacons and who should pay for their installation, operation, and maintenance.

4 Tolling

4.1 The National Architecture

4.1.1 Toll payment options

The architecture and resultant message sequences for Roadway Tolls, Transit Fares and Parking Payments have been designed in a similar way in order that one technology is able to serve all ITS payment services.

For Roadway Tolls, Toll tags[1] can be used to pay tolls using conventional methods. Financial transactions are secured by state-of-the-art encryption and authentication processes incorporated in the Physical Architecture Communications Layer. There is nothing in the

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[1]*In the National Architecture Toll tags are equivalent to OBE (on-board equipment). They are not necessarily 'dumb' tags but are described as stored value cards combined with DSRC technology.*

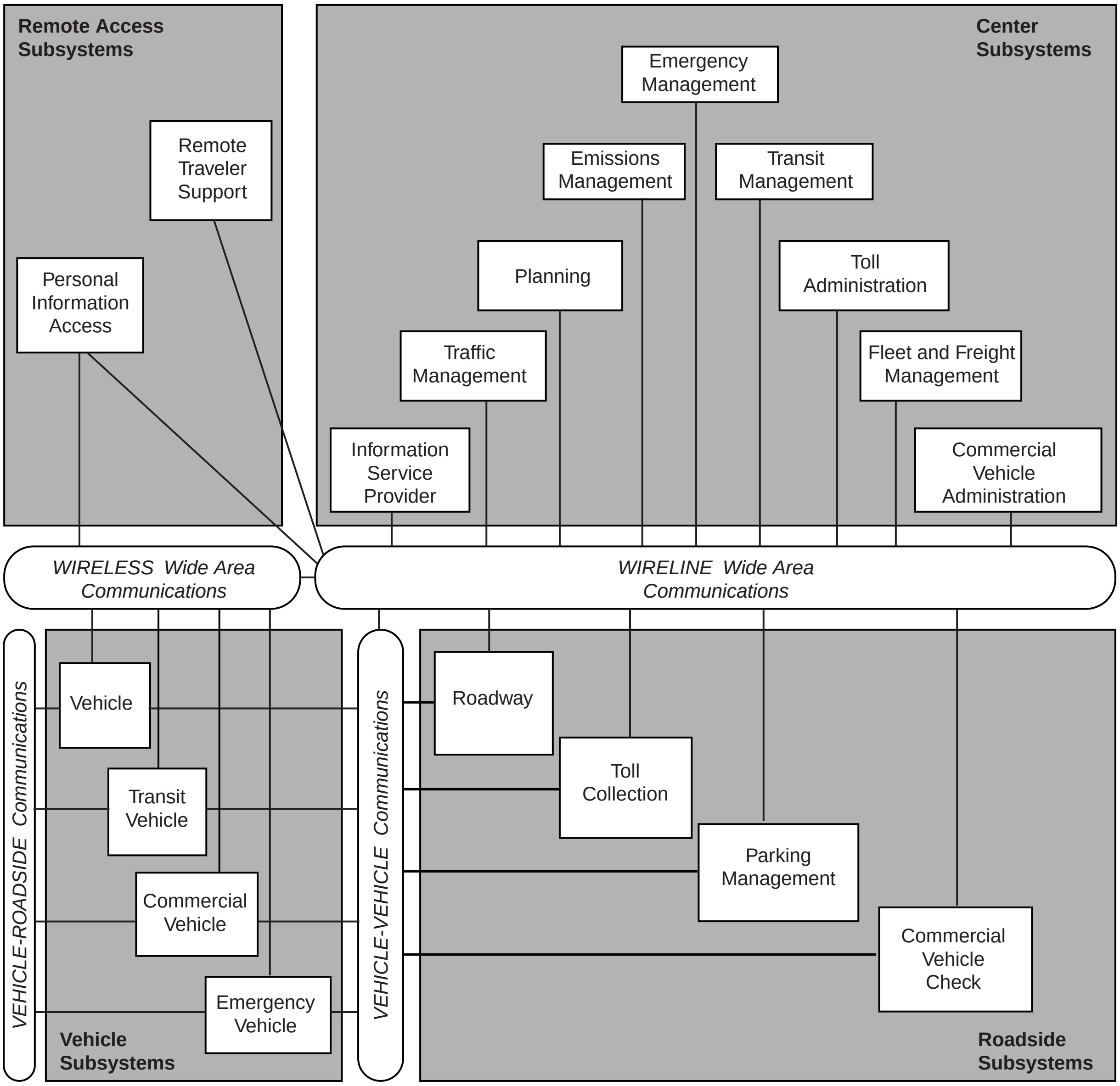

Figure 2 ITS Architecture sub-systems and communication elements (reproduced from ITS Theory of Operations)

architecture that explicitly disallows traditional cash mechanisms for toll payment.

It is claimed that three types of financial instrument cards will be supported by the architecture. These are described in the ITS Architecture: Theory of Operations (US DOT, FHA, 1996c) as follows:

Stored value cards

These cards have an encrypted value stored in memory on the card which is decremented at the point of sale.

Off-line reconciliation may be necessary if the card supports more than one vendor, e.g., for multi modal travel and/or other purchases. (The 'vendor' in this discussion can be a toll agency, transit agency, or parking lot operator). For example, if a transit agency supports stored value cards only for its own transportation services, reconciliation is not necessary. On the other hand, if the transit agency subscribes to use a card that can also be used for purchases of goods and/or services elsewhere, then reconciliation is necessary. Reconciliation requires that the point-of-sale equipment reads from the card financial institution and account information so that a back-end electronic money transfer can be effected for the sale. Reconciliation for individual cards may also be used to detect fraud. When reconciliation is used, each card has an individual reconciliation account associated with it, and its value is the amount of money 'stored' on the card minus the amount of all transactions. It is up to an individual agency or company to decide whether or not to issue their own stored value cards or to use a 'generic' card requiring reconciliation. If issuing their own card, they also have to decide whether or not to support reconciliation. This last consideration may be based on how secure they believe the encryption technology used to store the current value of a stored value card to be.

Cards can be purchased and value added to them with cash, providing total anonymity to the purchaser — although purchases with credit/debit cards may offer convenience and traceability benefits to the purchaser as well.

Debit cards

This card provides a financial institution identifier and an account number to be immediately debited at the time of the sale. Debit cards (and credit or charge cards) entail some financial risk on the part of the vendor unless they query the financial institution for the debit transaction at the point of sale. This is necessary to avoid later transactions that are denied due to lack of funds. This real-time financial institution transaction is not practical for toll, transit, or many parking applications. A strategy that has been worked out by the financial issuers of these cards for these situations is called 'preauthorization.' In preauthorization, a fixed amount of account balance or credit is put aside for the vendor to charge after the card owner has made one or more purchases. Since the funds are set aside, there is no fund availability risk to the vendor. After a fixed period of time, or after a number of transactions, an off–line charge against the set aside funds can be made to charge for the received services. This 'preauthorization' mechanism of 'prepayment' is also able to minimize individual transaction charges that card issuers may impose on vendors. These charges can be particularly onerous as a fraction of total charged services for relatively small charges such as some short distance tolls or some transit fares. Using preauthorization for debit, credit, and/or charge cards can enable them to approach the convenience of stored value cards for the vendor, with the benefits of convenience and traceability for the traveller (but without the benefit of total anonymity that a cash purchased stored value card provides).

Credit or charge cards

Similar to debit cards, except that the initial source of funds is from the card issuer, which is extended as a short term loan to the card user. With a charge card, users pay back the card issuer in full on a monthly basis. With a credit card, users have the option to pay back the card issuer in full similar to a charge card, or can accumulate some portion of the charges to a longer term loan by the card issuer to the card user.

Note that debit, credit, and charge cards are evolving features of stored value cards independent of ITS. The impact is to enable small value purchases while minimizing reconciliation transactions. The features of these cards will include the ability to add value to the cards from any bank ATM terminal, or possibly from personal computers with card proximity read/write capability and a connection to the Internet.

4.1.2 Toll collection

The National Architecture only supports electronic toll collection using DSRC. However, several methods of toll collection are supported using this form of communication. These fall into two general categories:

A Financial transactions that are handled entirely in the infrastructure. This uses a basic credit/ debit tag, with no stored value on the tag.

B Financial transactions that are accomplished on the tag or some other in-vehicle interface. This class of system uses a stored value card, or a smart card technology.

The basic transactions that the NA envisages to accomplish both types of system are shown in Figure 3.

The reader in the Toll Collection Sub-system (TCS) initiates the transaction by sending a request tag data (flow 1). The vehicle tag responds with tag data (flow 2). This will contain a credit identity in systems designated A above, and will include in addition the stored value in case B. For closed toll systems the tag data will also contain the location and time at which the vehicle entered the system. In these systems this information is used to compute the toll. The reader updates the tag (flow 3). In case A this includes only that the transaction has been accomplished. In case B the amount to be debited is included.

Another instance of the tag update message is where the vehicle is entering a closed toll system. In this case, the tag update message will contain the location and time of entry into the system.

It is important to note that Figure 3 depicts a very simplified overview of how a transaction will take place. It is likely that the transaction set in a real tolling application will be far more complex, but this is not described in the NA.

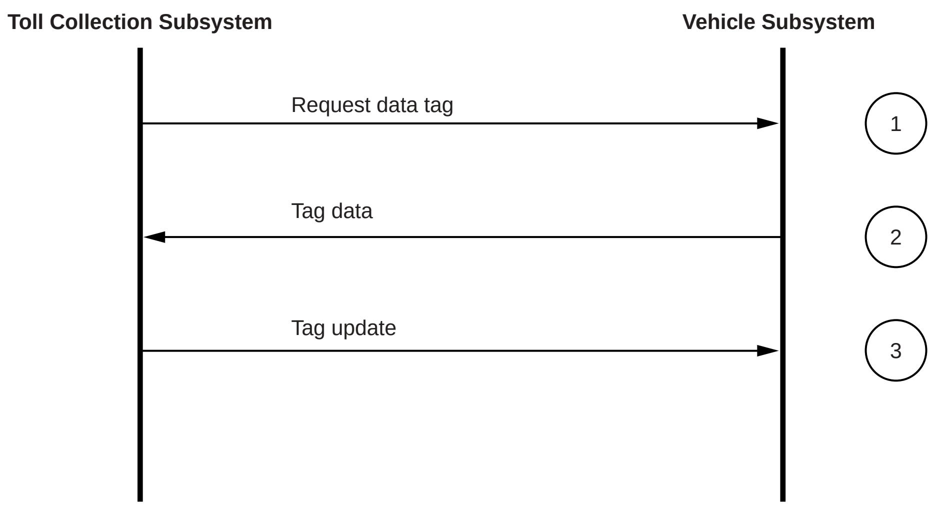

Figure 3 Electronic Toll Collection Transaction Set (reproduced from ITS Architecture Standards Development Plan. Standard Requirement Package 1: Dedicated Short Range Communications)

4.1.3 *The NA functional decomposition for a tolling application*

The NA documentation provides a detailed functional description of how a tolling application will operate within the National Architecture. This has been likened to that contained within the European CASH documents.

While the functional decomposition described in the logical architecture flows provides a useful guide to the vehicle to roadside communication, it could be construed as misleading. The data exchange for the toll collection transaction set indicates that only a single payment option is available to users. The roadside equipment requests a credit card number which is then transmitted by the OBE back to the RSE. As the functional decomposition does not appear to provide a mechanism for payment by debit or stored value cards, this may imply that users can not use these forms of payment.

4.2 Tolling in UK/Europe

In Europe, Dedicated Short Range Communication is intended to be a communication means for Road Traffic and Transport Telematics (RTTT) applications, including Automatic Fee Collection (AFC), Automatic Vehicle and Equipment Identification (AVI/AEI) and Traffic and Traveller Information (TTI). In particular it is anticipated that future European tolling systems will be defined in a series of TC278 draft pre-standards addressing different levels of the Open Systems Interconnection (OSI) model.

4.2.1 Automatic Fee Collection (AFC) model

The AFC Transaction Model related to the AFC Application Interface for DSRC comprises two phases, the mandatory initialisation phase and the optional transaction phase.

The purpose of the initialisation phase is to begin communication between the Road Side Equipment (RSE) and On-Board Equipment (OBE) that have entered the DSRC zone but have not yet established communication with the RSE, and to notify the application processes. The TC278 standards actually allow several Road Traffic and Transport Telematics (RTTT) applications to communicate (in parallel) with one RSE station. These applications are not restricted to just tolling applications.

Once the initialisation phase has been completed the transaction phase can occur. The Automatic Fee Collection functions themselves are be performed in the transaction phase.

The initialisation phase

It is proposed that the initialisation phase is performed by means of Beacon Service Table and Vehicle Service Table exchanges. The OBE evaluates the received Beacon Service Table and selects the applications that it wishes to perform, out of the list of applications supported by the Roadside Equipment (RSE). If the OBE does not support any of the application(s) supported by the roadside equipment, then the OBE does not exchange any information. If, on the other hand, the OBE supports at least one of the application(s) supported by the RSE, then the OBE sends its corresponding Vehicle Service Table, informing the RSE which application it wishes to execute.

The transaction phase

After completion of the initialisation phase, the appropriate Roadside Equipment application is informed (by means of the Notify Application Beacon service) of the service provider, the type of contract and the contracts version number. The roadside equipment then uses pre-defined functions to complete the transaction, e.g. an AFC transaction.

4.2.2 European harmonisation of AFC

There are two obvious routes towards harmonisation in Europe. The first approach would be to ensure that all member countries agree upon a standard method of tolling vehicles which would require, for example, that a pan-European vehicle classification system be devised. The alternative strategy would be to create standards which enable OBE to function in any country regardless of the way vehicles are tolled.

Although the first approach may be appropriate to the US situation, it is unlikely that it would be acceptable to EU members. The main problem is that countries already have existing legislation which govern taxation on different classes of vehicle. Individual countries may be keen to discourage certain types of lorries, or to discourage foreign vehicles (which do not contribute road tax) from using roads at a ‘discounted rate’. Therefore, in the short to medium term at least, harmonisation by the first approach is unlikely.

The other approach requires development of the OBE and the RSE using a standards based approach such as that proposed by the working groups of TC278. TC278 will permit AFC to occur across Europe providing that each individual user has contracts with the appropriate service providers. Each unit will be able to hold information on up to 16384 service providers (SPs). Each SP will also be able to issue different contracts in addition to contracts with different version numbers. The advantage with the CEN TC278 approach, in particular, is that each SP can choose to adopt a different set of vehicle classifications. Thus, OBE can function with different sets of vehicle classifications.

5 Other DSRC applications

5.1 Applications supported by the NA which can use DSRC

The DSRC link only appears to support electronic tolling and commercial vehicle electronic clearance in current deployments. However the architecture ‘envisions’ that parking management, automated highway systems and in-vehicle signing could also utilise DSRC in the future.

DSRC communication is best suited for applications where services will benefit from the location specific nature of each beacon installation eg:

- Parking systems
- Highway/rail crossings (a possible future ITS user service)
- Toll systems
- Transit systems (e.g. fixed urban route)
- Traffic probes (using ETTM tags)
- Intersection collision avoidance
- In-vehicle signing.

It is not anticipated that Route Guidance will be given via DSRC.

Note that beacons for in-vehicle signage are generally viewed by the architecture documentation as very simple, low cost modules that simply broadcast fixed signage information. For example, it is suggested that these beacons could be powered by solar cells and would not require a wireline communication interface.

Wide area wireless communication, on the other hand, is best suited for services benefiting from near ubiquitous coverage e.g.:

- Traveller information
- Commercial vehicle operations/fleet management
- Emergency response

5.2 Applications which may use DSRC in UK and Europe

There are functions, other than electronic toll collection, which may be designed to use DSRC - these have been called ‘Medium Range Pre-Information’ in the Prometheus Project.

Current European projects in this area include RTA in the UK, Companion in Germany and ADAMs in France (which may be brought together under a European umbrella project with other interested countries).

Applications include:

- driver and bus passenger information
- speed advice delivered into the vehicle (which may or may not provide speed control)
- engine management advice from roadside to vehicle
- probe vehicle information (status of wipers and lights etc) from vehicle to roadside.

It is envisaged by participants in these projects that some of these services could be provided by independent service providers and some form of payment made (probably in advance for a decryption key).

5.3 Comparison between DSRC applications proposed in US and Europe

See table page 10.

6 Standards

6.1 National Architecture

It is as important to look at the likely standards which will emerge from the NA as much as the architecture itself as these represent ‘deeds rather than words’. As the Dedicated Short Range Communications Standards Requirements Package (SRP) states (Section 1.1) (US, DOT, FHA, 1996) SRPs ‘represent the distillation of stakeholder interests and architecture interoperability requirements’.

In the opinion of the NA, the Communication Layers for Dedicated Short Range Communications are strong candidates for standardisation in order to achieve national interoperability. The DSRC links described in the ITS Architecture: Standards Requirements Packages 1: Dedicated Short Range Communication, have the following requirements:

- High reliability: P(bit error) <10^{-6} when vehicle is moving at speeds up to 200 km/h by a fixed roadside reader and with vehicle transponder separation of a minimum of 0.5 metres.
- High data rates [typically 300-600 Kb/s].
- Two way communication is a general requirement for DSRC, and the DSRC link should be able to support duplex communications. [Although there are some applications, e.g. in-vehicle signing, requiring only one way communications].
- Utilise one frequency band for transmission and receipt of signals. (It is advantageous for national interoperability for all DSRC systems to be using the same basic frequency band, otherwise national interoperability can only be achieved by having readers which work at multiple frequency bands.) [Currently the band being utilised is 902-928 MHZ. There is increasing interference from other non-ITS sources in this band, so a move to the 5.8 GHz band is being considered. A band very near this has already been specified in Europe for DSRC applications].
- No network layer requirements- only physical layer and data link layers are required. [There are some implementations of DSRC which utilise a network layer to achieve separation between adjacent beacons. The roadside beacons will be part of a network, but the beacon to vehicle link typically will not be].
- Utilise an open communications protocol. [At the Data link layer this could be a High Level Data Link Control (HDLC) or a non-proprietary Time Division Multiple Access (TDMA) protocol].

6.2 European DSRC and related standards

6.2.1 Working groups covering tolling and DSRC

There are two main standards groups within CEN and ISO which are concerned with both DSRC and tolling. They are CEN TC278 and ISO TC204. Although much of the work is duplicated between the two groups they often share the same members and work collaboratively. The table below concisely highlights the foci of the work packages in TC278 and ISO TC204 which are relevant to DSRC and tolling (see table page 11).

6.2.2 Development process for CEN standards

The procedure described below is the CEN process applicable to Transport Telematics. It focuses on CEN procedures in situations where no international standards (that could be adopted) exist.

When a standardisation item has been identified, it is described in a special format, providing information on the deliverable type intended, rationale, resources needed, time plan, etc., and a proposed allocation to a workgroup (WG). Normally, a work item (WI) should end in a defined deliverable, in CEN/TC278 an EN, ENV or ITR.

The internal workings of a WG are not normally publicly available. When the WG has reached a result for its own satisfaction, it submits its result to the Technical Committee (TC) for comment. This event in CEN is

Application	DSRC America	DSRC UK/Europe
Toll Payment	Yes. Positive vehicle location and payment transaction with low cost in-vehicle equipment.	Yes, but GPS/GSM also still a possibility.
Parking Payment	Yes. Positive vehicle location and payment transaction at the parking location with low cost in-vehicle equipment.	Yes, DSRC could support a system for drivers to reserve a parking space and pay in advance for parking.
Parking Pre Payment	No. Prepayment / reservation is difficult with beacon alone because it is hard to assure that the 'confirmation' (that a space is available) downlink message can be sent to the vehicle via beacon.	Yes this has been demonstrated in GAUDI and ADEPT.
Commercial Vehicle Checking Operations	Yes. Note that processing latencies between the initial vehicle tag read by beacon and the 'pass/pull-in' message by beacon may be tolerated if a pair of beacons are used on a stretch of road prior to the Commercial Vehicle Check sub-system, separated by enough space such that vehicles travelling at maximum mainline speeds will reach the second beacon for the 'pass / pull-in' message after the worst case processing latency time.	Yes.
Transit Vehicle Operations	Yes, for uplink of operations data and downlink messages that go to all transit vehicles.	Yes.
Transit Vehicle Signal Priority and Emergency Vehicle Signal Preemption	Yes. Direct vehicle to roadway signal.	Yes.
In Vehicle Signage	Yes, but only for a limited range of functions. Emphasis is on standalone beacons.	Yes, and more sub-functions than the US have been specified. Emphasis is on networked beacons.
Vehicle Navigation (Route Selection in Vehicle)	No. Either link time variances or suggested routes can be broadcast at each beacon site. Because of the limited time a vehicle is in the field of the beacon, some significant compromises must be made to select the information sent to the vehicle e.g. complete information local to the beacon, and sparse information remote to the beacon. Vehicles must delay getting real-time information updates until they reach a beacon - when the information may have become 'stale'. Dense deployments of beacons to counter this effect may be prohibitively expensive.	Not ruled out. European projects have shown that commercial route guidance systems can be adapted to respond to dynamic information broadcast via RDS-TMC using the ALERT-C protocol. This has been formalised in a functional specification for Dual Mode Route Guidance (DMRG - static and dynamic). This is based on the integration of autonomous navigation, RDS-TMC and dynamic route guidance via beacons.
Vehicle Navigation (Route Selection in Infrastructure and optionally coordinated with ATMS)	No. The worst case request / response latency will generally be longer than the time it takes a vehicle at mainline speeds to transit the beacon field of view. Furthermore, traveller requests for real time information or routes will have to wait for responses until the vehicle passes a beacon. This may not give satisfactory perceptions of service.	Not ruled out.
Emergency Request	No.	No, difficult to see how this can be accomplished.
Sources: NA DSRC information: ITS Architecture, Theory of Operations. Other information collated by TRL.		

CEN TC278 Road Transport and Traffic Telematics (RTTI)	ISO TC204 Transport Information and Control Systems
● WG1 Automatic Fee Collection and Access Control Sub-Group 1 (SG1) is concerned with creating a standard for the overall architecture for Automatic Fee Collection (AFC) systems. The AFC architecture has been linked to the TICS Fundamental Services to ensure that there is a degree of conformance with the definitions.	● WG5 Fee and toll collection Subgroup structure: SG1 Interfaces between operators SG2 DSRC fee collection SG3 Requirements for IC cards SG4 Security and Fee collection SG5 Cellular and satellite communication based fee collection
● WG4 Traffic and Traveller Information This workgroup is looking at the elaboration of standards for the coding of (mainly traffic related) data which can be transmitted through several communication systems, and more particularly: - radio broadcast though RDS format - cellular phone - DSRC	
● WG9 Dedicated Short Range Communication 'WG9 of CEN is the 'leading group' for DSRC standardisation according to the Vienna and Geneva agreement between ISO and CEN representatives'. Subgroup structure: SG1/2/3 OSI-Architecture requirements. SG L1 Physical Layer and Medium SG L2 Data Link Layer (MAC +LLC) SG L7 Application Layer SG 4 Communication Profiles Convener: J Kossack	● WG15 Dedicated Short Range Communications for TICS Applications WG15 was constituted in order to propose a common air interface standard for the DSRC link. WG15 has made a resolution to explore and develop the work of CEN TC278 WG9 and the work of other National and Regional Groups in order to pursue an international standard in the shortest possible time. Convener: J Kossack

referred to 'Stage 32' (working document circulated to technical body). This document is then circulated for comment and then forwarded on to the Central Secretariats (CS) for a final vote.

A prENV, is an ENV proposal which has been finally accepted by the TC. This document is sent directly to members for final vote, 'Stage 49' (Document available for final vote). The voting period is normally two months (extendible to three) and comments are only allowed to motivate negative votes. This means that it is only in the TC treatment of the proposal that the technical content can be influenced.

6.2.3 Some relevant documents covering tolling and DSRC

Through the course of TRL's assessment of the National Architecture, documentation relative to tolling activities has been uncovered. The following documents are mainly concerned with the standards development process:

ISO/IEC 7498-1:1994	Information Processing Systems – Open Systems Interconnection – Basic Reference model
ISO 7498-2:1989	Information Processing Systems – Open Systems Interconnection – Security Architecture
ISO 8824:1992	Information processing systems – Open Systems Interconnection Specification of abstract syntax notation one (ASN.1)

(See tables page 12)

6.3 Current tolling and DSRC standard issues

In October 1996 five major US wireless companies voiced their support for the Comité Européen de Normalisation (CEN) DSRC draft standard as the basis for an interoperable standard in the United States. In a letter sent to ITS America the companies wrote, 'As members of the

DSRC draft prENV at stage 32 for comments (N numbers from TC278)		
Document identifier	*Description*	*Date of approval*
Doc. N474	Ref. 00278053 **DSRC Data Link Layer** (ready for stage 49, but not yet circulated for voting)	Oct 95
Doc. N505	Ref. 00278051 **DSRC Application Layer** (ready for stage 49, but not yet circulated for voting)	Sep 95
Doc. N526	Ref. 278/9/#63 DSRC Physical Layer using IR at 850 nm (A new version 9/96 is ready for stage 49, but not yet circulated for voting)	Dec 95
	Ref. /278/9/#74 DSRC Profiles for RTTT Applications	TBA

prENVs at stage 49 or later for Formal (national) vote		
Document identifier	*Description*	*Status*
prENV 12315-1	TTI Messages via DSRC, Part 1: Data spec. - downlink	approved
prENV 12315-2	TTI Messages via DSRC, Part 2: Data spec. - uplink	approved
prENV 12314-1	AVI/AEI - Part 1:Reference Architecture and Terminology	approved
prENV 12314-2	AVI/AEI - Part 2: Numbering and Data Structures	not approved
prENV 12253	DSRC Physical Layer using MW at 5.8 GHz	not approved

ITS community, we have participated in the development of DSRC standards and recognise the importance of these standards to accelerate the development of ITS systems. It is our belief that the CEN draft is the most appropriate basis for a standard, and we will work toward the adoption of this system as the new standard for all DSRC applications in the United States'. Although the CEN draft has undergone extensive testing and has widespread support in America, Europe, Asia and Australia there have been accusations that the promoted standard is the work of a 'cartel'. In particular, certain European manufacturers believe that the 5.8GHz standard proposal is based on too narrow a bandwidth.

Although consensus has not been reached on the CEN TC278 layer 1, the problems have been largely political and commercial rather than technical. Italy voted against the proposed standard because they already possessed their own system, and wished for a wider bandwidth. On the other hand, certain countries called for a lower bandwidth in order to reduce system costs as data communication rates would be lower.

6.3.1 Status of DSRC draft standards from CEN TC278 WG9

DSRC standardisation was discussed at the last ISO TC204 WG15 meeting, held in Orlando on 9th October 1996. The following text is an extract from the meeting's minutes.

Currently, the CEN (pan-European) standard is ready for voting at the national level. However, the Central Secretariat has held up the vote (for several months) in order to attempt to resolve some possible conflicts before voting takes place. The conflicts do not result from detailed technical issues ('the CEN draft documents are technically stable') but from two primary concerns. First, there are several nations that have already deployed DSRC that are not CEN compatible. It is not clear how these systems will interact/interfere with the CEN standard. A second related issue is the desire to see more emphasis on a lower and higher data rate. Currently, the CEN standard consists of five documents: a microwave physical layer standard, an infrared physical layer standard, a medium access protocol layer standard (data link layer), an application layer standard and a profile document (which is a guide for deployment). The profile document focuses only on the default data rate of 500 kpbs. This rate was selected due to a CEN study that looked at applications versus data rate requirements. The 500 kbps rate was a compromise. Some nations would like to see profiles for other data rates. It was noted that lower data rates (may) have some advantages due to cost and complexity while higher data rates are needed to support more advanced applications. Discussion led to suggestions that data rate could be associated with *either geographic regions or applications. It should also be noted that there are other issues that are slowing the pan-European deployment of DSRC. One key issue is the ability to 'roam' (i.e. operate as if you were enrolled in the national system) from one national system to another. There is an underlying lack of harmonisation which is keeping nations from sharing security information (key exchange) for example.*

Due to the potential conflicts noted above, the working group wanted to propose to the CEN TC278 Central Secretariat to hold a Meeting to develop a migration strategy. This Meeting would lay the groundwork for developing a migration plan that encourages users to deploy the standard. It was suggested that the plan should focus on the technical issues first to limit the number of potential policy issues.

6.3.2 Status of ISO TC204 standards

The next step in the standard development process is to ask technical committee members for comments on documents N177-N180 within a time limit specified by the ISO regulations. An extract from the minutes of the meeting is highlighted below.

The comments will be received by WG 15 and passed to CEN TC 278 WG9. Nations with comments are invited to TC 278 WG9 to present/ defend comments. Note that CEN TC278 WG9 has the lead on DSRC standards development in the international community as a result of the Vienna Agreement. Therefore, ISO TC204 WG15 collects the comments from the non-European nations and passes them on to TC278 WG9. Due to this arrangement, there was some concern that WG 9 would not make a concerted effort to internationalize the standard. Several suggestions were made to address this issue. This includes making separate appendices for geographic regions, moving spectrum requirements from the normative to suggestive section, or extending the standard by defining a new set of communication profiles. Many of the suggestions attempted to address the spectrum limitations in some regions of the world (only 10 MHZ available in Europe at 5.8 GHz). The WG decided that to support international harmonization, it would be useful to pursue extending the standards parameter list and adding new communication profiles to cover specific regions.

7 Conclusions and recommendations

7.1 The roll of DSRC within the NA

Beacon communication capability is likely to be used by Roadway and Vehicle sub-systems where the cost of the beacon communication equipment is less than the cost of the equivalent Wireless communications infrastructure. For example, the NA documentation suggests that toll and parking payment operations, commercial vehicle operations or urban fixed route public transit operations *may be* most economically served by beacon communications for messaging between the vehicles and the appropriate Roadway or Centre sub-systems. In these cases, the specific costs and sources of initial capital as well as operations and maintenance expenses must be considered.

Despite the presence of inter-networking within the NA, the format of information which can be transmitted to a vehicle via DSRC is limited by the data structures which are embedded in the National Architecture. Thus, in the authors' opinion, these structures will effectively limit the type of information which can be transmitted between a vehicle and the roadside infrastructure if the proposals in the NA documentation are rigidly adhered to.

7.2 Limitations of the US approach to tolling and DSRC

- *Too prescriptive*

Although some commentators have stated that the NA is a general framework that incorporates all options; this is not considered the case. Specific choices have been made to restrict the role of DSRC and this may not be compatible with UK thinking. For example, it is implied that Information Service Providers (ISPs) will generally supply information to vehicle sub-systems via wireless wide area communication. However, in many instances there will be a requirement for localised driver information (eg. petrol prices) which is more suited to DSRC communication. Furthermore, the NA does not support certain driver applications (e.g route guidance) using DSRC.

- *Data structures need to be extended and developed*

The Architecture only appears to really consider applications in the near future which will use DSRC. It is not evident from the NA that its data structure will allow the transfer of unspecified information in applications. For example there may be a future requirement to transmit certain information e.g 'fog lights on' from the probe vehicle to the roadside. At the present the architecture does not cater for this form of data transfer.

It is therefore concluded that the granularity of the NA definitions is too fine and that the low level communications protocols should be developed by European/International standards workgroups rather than forming an integral part of the architecture 'package' presented in the documentation.

- *Different perspectives*

The US authors themselves have slightly different perspectives of the role of DSRC in the US architecture, as each document (or set of documents) provides an alternative outlook on the architecture.

Additionally, American and European perspectives differ. The human geography of the US has made a large impact on the choices made within the NA. Population centres are, on the whole, separated by comparatively long distances and it is not anticipated that these inter-urban corridors will be equipped with DSRC. As the choice of communication technology appears to be largely dependent upon cost, the architecture will be more reliant on wireline and on other forms of wireless communications.

- *Limited role of DSRC*

Very few driver applications specify using DSRC, and the architecture states that its main uses will be for electronic toll collection and freight/fleet vehicle communication. Collision avoidance at junctions may use DSRC. In addition limited information will also be sent from probe vehicles to networked roadside beacons.

However, the NA plan expects that a large proportion of driver information will not be transmitted to the vehicle via DSRC, and will use wireless wide area communications instead. Information Service Providers (ISPs), Personal Information Access and Remote traveller support are all likely to use wireless communications in the National Architecture.

- *Medium Range Pre-Information (MRPI)*

The National Architecture does not appear to support MRPI applications such as driver and bus passenger information via DSRC. The provision of such information using DSRC is ideally suited to the UK situation, and trialing of bus passenger information is scheduled in the Road Traffic Advisor project.

Furthermore only a restricted set of probe vehicle information is defined by the architecture. It is expected that vehicles in the UK could transmit a much wider range of information back to the infrastructure. Other areas such as speed advice delivered into the vehicle, and engine management advice from roadside to vehicle are not adequately catered for by the NA.

The NA documentation gives the impression that in-vehicle signage DSRC beacons would remain un-networked in the US. These ‘dumb’ beacons could only be used to transmit one-way information to vehicles e.g speed limits. However, it is considered that this approach is not appropriate for the UK as it is envisaged that speed limits may be dependent on a wide range of factors. The traffic flow or weather conditions may necessitate a temporary reduction in the speed limit, as would an accident on the carriageway.

7.3 Recommendations

- *Medium Range Pre-Information (MRPI)*

European systems should be designed with a greater emphasis on networked beacons. A wider range of information both from and to vehicles should be considered. Furthermore, data structure and data dictionaries should be developed through appropriate standards bodies.

MRPI has the scope to improve driver safety and reduce travel times. It is recommended that European standardisation work continues (cf. CEN TC278 WG 4.2) and is enhanced by using the experience of projects such as RTA and ADAMS. A non-exclusive list of possible MRPI applications which would be suitable for standards development are as follows: road and traffic conditions related to the immediate route of the vehicle, fleet management, services based on dynamic announcement, and inter-connection with other modes of transportation.

- *Route guidance*

In the NA, route guidance using DSRC is specifically not supported. While it would be unfeasible to transfer all route guidance information to a vehicle, it is possible that dynamic information (from DSRC beacons) could be transmitted to supplement static route information stored in-vehicle (e.g CD-ROM maps). It is anticipated that dynamic route guidance information could be transmitted in this way in the short to medium term. In the long term it may be advantageous to determine centrally route guidance for vehicles. Economics and commercial pressures are likely to drive the market, which should not be overly restricted by architectures.

- *Standards for AFC*

Although the information contained within the DSRC Standards Requirements Package is provided in an ISO standard ‘format’, the document states that ‘the material in the Architecture, while comprehensive, is typically not at a sufficient level of detail that it can be transitioned directly into a draft standard’. Nevertheless US Standards for DSRC (based upon the functional decompositions within the NA) will be too restrictive (as well as incompatible) for use in the UK.

It is therefore recommended that the UK adopts the CEN approach towards AFC harmonisation in Europe. There is also a great deal of flexibility associated with the OBEs, as each service provider can store a large number of contracts within the equipment. In addition the way a vehicle is classified will be dependent upon the SP. Therefore, even if different European countries use different vehicle classifications systems then there should not be a problem of interoperability across national borders.

- *Common Telematics Infrastructure*

Limitations have been placed on the use of DSRC within the NA mainly because of cost implications. However, many in-vehicle applications would be suited to DSRC in the UK and it is important that applications are not ruled out because they do not appear in the US architecture.

The commitment to a national tolling infrastructure based on DSRC would be a substantial boost to the provision of additional ‘value added’ services over DSRC. Without a national infrastructure UK firms will be unlikely to invest money developing (DSRC) applications. It is therefore recommended that the UK commits to a national infrastructure.

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Abstract

TRL has undertaken a review of tolling and DSRC communication aspects of the US National Architecture (NA) on behalf of Department of Transport (now Department of the Environment, Transport and the Regions) Tolling & Private Finance Division (TPF2).

It is concluded that the NA has made specific choices in the areas of tolling and DSRC which may not be appropriate for the UK and Europe.

A number of recommendations are made concerning the development of DSRC information services and development of standards for tolling.