Recommendations on microwave DSRC technologies at 5.8 GHz to be used for the European electronic toll service

Prepared by

Expert Group 1: Microwave technologies

working with support of the European Commission DG TREN
on the work in Directive 2004/52/EC

Document name:	EG1 final report 14March2005.doc
Status:	Approved by EG1
Document nature	Report prepared for EC DG TREN
Dissemination level:	EFC Expert Group
Date of issue:	14 March 2005
Contact persons:	Jesper Engdahl

Rapp Trans
Tel: +41 61 335 78 53
Fax: +41 61 335 77 00
E-mail: jesper.engdahl@rapp.ch

Philippe Hamet
European Commission DG TREN
Tel: +32 2 295 18 61
E-mail: philippe.hamet@cec.eu.int

Table of contents

1 Scope 3
1.1 The task of EG1 3
1.2 Scope of the task 3
2 European EFC 5.8 GHz state-of-affairs 4
2.1 Main characteristics 4
2.2 Overview of deployed 5.8 GHz technologies and systems 5
3 Appraisal of the Italian Telepass Specifications 6
3.1 Introduction 6
3.2 Main findings 7
4 Technical interoperability using DSRC at 5.8 GHz 8
4.1 What it means 8
4.2 Approaches to interoperability 9
4.3 Guiding principles 9
5 Concepts 10
5.1 Introduction 10
5.2 Common DSRC stack and EFC application 11
5.3 Multi-protocol OBU 11
5.4 Multi-protocol RSE 13
5.5 Dynamically configurable OBU 13
5.6 Summary 15
6 Analyses 16
6.1 Introduction 16
6.2 Operational and technical evaluation 16
6.3 Financial impact 18
6.4 Overall reflections 22
Annex A – Members of expert group 1 24
Annex B – Glossary of terms 24
Annex C – Reference Lists 25
Annex D – Frequency regulations, spectrum and use 27
Annex E – Qualitative evaluation 29
Annex F – Interoperability – France and Norway 55
Annex G – CEN EFC new work items 56
Annex H – Overview of European EFC systems 60
Annex I – Reflections on OBU classes 69
Annex J – Reflections on OBU costs 70

1 Scope

1.1 The task of EG1

European Directive 2004/52/EC deals with the interoperability of electronic road toll systems in the Community. The Directive sets a target date of July 2006 for international agreement on the definition of the European Electronic Toll Service (EETS).

It is expected that OBUs will be provided to users wanting the EETS service by any authorised Issuer for use with all eligible charging schemes across Europe.

Expert Group 1 (EG1) on microwave technologies was established by the European Commission to provide analyses on the inclusion of microwave DSRC technologies at 5.8 GHz to be used for the EETS, in support of the European Directive 2004/52/EC.

This paper provides the result of EG1's analyses to EC DG TREN for implementation of EETS using DSRC at 5.8 GHZ.

EG1 comprises six experts, selected by the European Commission on the basis of their experience.

1.2 Scope of the task

The key task of EG1 is to investigate the following concepts and their suitability to form the basis for the EETS at 5.8 GHz:

1. **Common DSRC stack and EFC application** supported by all eligible on-board units (OBUs) and roadside equipment (RSE).
2. **Multi-protocol OBU (CEN, Telepass, …)**: more than one DSRC stack or/and EFC application supported by the OBU
3. **Multi-protocol RSE (CEN, Telepass, …)**: more than one DSRC stack or/and EFC applications supported by the RSE
4. **Dynamically configurable OBU**: the "EFC application" is downloaded, e.g. via GPRS, whenever "entering" a new EFC domain

In addition, EG1 was asked to highlight areas where further work is needed in order to define the EETS at 5.8 GHz.

It was agreed that EG1 as part if its analyses should take into account:

- the European EFC state-of-affairs (see section 2), providing the overall context
- appraisal whether the Italian specifications [UNI DSRC, UNI AID] support an open vendor market of Telepass compliant OBU and RSE from a technical point of view (see section 3)
- guiding principles used as the basis for the elaboration of the investigated concepts (see section 4.3), such as "the DSRC 5.8 GHz transaction for EFC charging associated with the EETS is based on central account charging"
- the assumptions, properties and open issues of the four investigated concepts (see section 5)
- analyses of the technical, operational and costs associated with the examined concepts (see section 6)

It should be noted that the following issues were not part of the assignment:

- Charging transaction requirements including security services and the management at the toll service charging points
- DSRC communication requirements specification
- Urban road user charging requirements (single pole, side mounted, insulation of traffic direction, etc)
- Integration of the OBU into the vehicle (scope of Expert Group 6)
- “Interface” to other in-vehicles EFC technologies such as GNSS/CN and GPRS

2 European EFC 5.8 GHz state-of-affairs

2.1 Main characteristics

Deployment of electronic fee collection (EFC) in Europe is predominantly based on the European DSRC 5.8 GHz technology.

Whereas the deployed EFC systems in Europe have much in common, they also display major differences e.g. in terms of technology and charging principles (i.e. whether it is based on network-, distance- or zone/congestion).

The tariff principle is one of the main reasons for differences in the classification parameters used and how the fee is calculated. The security architecture is also one of the main reasons for the differences, e.g. access to data stored in the OBU and the different security mechanisms to protect the integrity of the data.

Heavy goods vehicle (HGV) distance-based charging and urban road user charging[1] are two relatively new market segments. The first implementations of HGV charging systems[2] in Europe are found in Switzerland, Austria and Germany, and are based on different principles and technologies. The Austrian, German and Swiss OBUs are very different from one another. The former is a monolithic OBU, whereas the two latter are relatively complex (DSRC, external power, GPS, tachograph, vehicle movement sensor etc) and need mounting by authorised agents.

In general, the current European EFC OBU served exclusively by DSRC 5.8 GHz technology has the following typical characteristics:

- **Focused design**: EFC for single lane and multi-lane environments.
- **Inexpensive end-user equipment**: mass-produced, inexpensive (approximate price 15-20 EUR) with a product life cycle of 2-4 years.
- **High speed**: predictable and reliable performance in constrained low speed toll lanes to mainline speeds (up and beyond the authorised speed limit). Claimed transaction error rates are typically less than 1 in 10,000 in all environments.
- **Well-defined dedicated communication zone**: vehicle-to-roadside communication link over a distance of typically less than 10-15m

[1] UK's TfL assesses different technologies and their suitability to provide flexible and cost-effective operations of urban road user charging schemes.

[2] UK's HMC&E is currently procuring the LRUC system. Other countries, such as France, Sweden and Slovakia, plan to introduce HGV charging systems.

- **Self-mounted**: OBUs are designed to be distributed through retail outlets, automated vending machines and by post. This ensures high market penetration with limited (or no) operator installation support.
- **Harsh environment use**: traffic and transport, capable of operation between extremes of air temperatures from parked vehicles in direct sunlight to sub-zero temperatures
- **Autonomous**: No interface to the vehicle. The OBU is simply fixed to the windscreen with a proprietary holder
- **Low lifetime cost**: long battery life, from 3 to 6 years is typical for an OBU with a simple human machine interface (HMI).
- **High volume**: around 10 millions[3] OBUs have been issued in Europe with typical project batch sizes between 50,000 and 200,000. Start up volume batch sizes are sometimes greater based on forecast of initial adoption rates.
- **Simple to use**: simple HMI including an audible indicator and, in some cases, chipcard reader, an array of light emitting diodes, liquid crystal display interface.

Whilst elaborating on interoperability of all EFC systems operating in Europe, with their sometimes different requirements with respect to in-vehicle technologies (DSRC, GPS, GSM/GPRS, chipcard reader, tachograph, gyro vehicle sensors …), it may be worthwhile to consider clustering of OBU requirements into groups in order to provide suitable solution for different groups of users / operators (see Annex I).

2.2 Overview of deployed 5.8 GHz technologies and systems

There are **two main EFC 5.8 GHz technologies** that are deployed in Europe, the European standard and the Italian Telepass technologies.

The **European standard** EFC 5.8 GHz technology is based on the CEN Standards for DSRC [CEN DSRC] that define layers 1, 2 and 7, and that provide an application layer to the application users. The CEN standards support two parameter sets (known as L1-A and L1-B). Practical compatibility of these to parameters sets was proven in 2003 through laboratory and field tests carried out by the Federation of French motorway and toll facility companies (ASFA) and the Norwegian Public Road Administration (NPRA), see also Annex F. The EFC standard [EFC AID] defines a generic transaction model, EFC functions and application data and the rules for addressing data. The associated EFC test standard [EFC AID Tests] defines OBU conformance test procedures.

Telepass technology, based upon UNI-10607 standard, is deployed in the nation-wide Italian EFC system. The Italian specifications [UNI DSRC, UNI AID] largely mirror the communication architecture of the European standard for DSRC and EFC.

In addition it should be noted that:

- The **Portuguese 5.8 GHz "low data rate**" system is currently **migrating** to become "**CEN DSRC EFC**" compliant; and
- Systems using other technologies than microwaves at 5.8 GHz are outside the scope of EG 1; the current national **Slovenian 2.45 GHz system** (that is **migrating to CEN DSRC EFC at 5.8 GHz**), and the German HGV Tolling System

An estimated 10 million OBUs have been issued in Europe, of which 4 million are Telepass OBUs in Italy. It is expected over time, as EFC becomes more widespread, that the number of

[3] The CEN DSRC 5.8 GHz technology is used also in Australia, SE Asia, South America and Southern Africa.

OBUs issued in the different member states will reflect the motorization [see e.g. 10.1 in European road statistics 2004] in various countries. Approximately 10'000 EFC lanes have been installed in Europe until today, of which some odd 2'000 are in Italy. The annual growth of OBU and EFC lanes in Europe is approximately 10-15%.

International interoperability between EFC systems based on the CEN 5.8 GHz technology exists between Switzerland/Austria[4] was also demonstrated in the French/Spanish commercial pilot in the PISTA project. The Nordic countries also strive to achieve interoperability during 2005, through the NORITS initiative. The **interoperability** of these systems is all **based on the CARDME / PISTA[5] charging transaction specification**, or dialects thereof and makes use of a common set of standardised functions and data.

The German HGV OBU provides a DSRC 5.8 GHz link according to CEN DSRC that is not used in the German HGV system but that is intended for interoperability with other European EFC systems after the German HGV OBU has been updated with the appropriate set of EFC application data and functions.

The MEDIA project – encompassing Alpine EFC operators (France, Italy, Slovenia, Austria and Switzerland) - is currently studying the prospect of introducing an interoperable service for Heavy Goods Vehicle (HGV) based on central account charging and a dual-protocol OBU.

3 Appraisal of the Italian Telepass Specifications

3.1 Introduction

This section reports on the results of the analysis of the Italian standard [UNI DSRC, UNI AID] that is composed of four parts and that carries largely the same contents as the European DSRC and EFC standards.

The overall aim of the analysis was to **appraise whether the Italian specifications [UNI DSRC, UNI AID] support an open vendor market of Telepass compliant OBU and RSE** from a technical point of view, and hence their level of completeness and consistency.

Further, the analysis also assessed the related regulatory issues, functional and operational aspects.

The impact of including Telepass as part of the EETS is evaluated in section 6.

Intellectual property and patent rights have not been investigated. However, it is noted that neither the Telepass specifications, the technology nor the dual protocol solution are subject to any intellectual property rights to the best of the knowledge of the members of EG1.

Whereas as the conducted analysis was comprehensive, it was not exhaustive as it was performed in a relatively short time frame and by a few persons. It is reasonable to believe that additional issues would be raised if the specifications were to be subject to further analysis and implementation by manufacturers. However, it is the opinion of the members of EG1 that all major issues have been identified and examined.

---

[4] The Swiss OBU (with distance recording features) can be used in Austria, whereas as the Austrian OBU (without distance based recording features) cannot be used in the Swiss distance based charging system.

[5] [CARDME] / [PISTA] that selects EFC functions and attributes from the underlying EFC standard [EFC AID].

3.2 Main findings

Level of completeness and consistency

Whereas the assessed specifications [UNI DSRC, UNI AID] are relatively complete, the following ambiguities and missing information need to be resolved and detailed in order to ensure equipment compatibility and an appropriate technical support for an open vendor market in the same way as the CEN standards [CEN DSRC, CEN EFC] do. It should be noted that the Italian specifications [UNI DSRC, UNI AID] are being updated (also as a consequences of this analysis), at the time of writing of this report, with the aim to provide a completed set of specifications and to resolve the identified issues below:

- **Layer 1**. The following parameters must also be specified:
  - OBU minimum receive frequency range
  - Angular emitted isotropically radiated power (EIRP) mask
  - Maximum single side band EIRP (at bore sight and within a 35 degrees cone)
  - OBU conversion gain – upper limit
  - Profile handling mechanism; interaction of the DSRC layers including the mechanism for profile handling, including the selection of sub-carrier frequency, sub-carrier modulation, uplink bit rate. This is indeed spread over Layer 1, Layer 2, and Layer 7.
- **Layer 2**. The following clarifications must also be specified:
  - Link address establishment procedures
  - The data collision and error recovery procedures
  - Communication link timing requirement, e.g. for OBU response in "responding mode"
- **Layer 7 and application interface definition** also need to include the following:
  - Definition of application data elements, including coding format, addressing mechanisms and semantics
  - Definition of EFC functions, including the addressing mechanisms
  - Detailed description of a complete transaction sequence analogous to the bit-level transaction example in the EFC standard [Annex B in EFC AID].

In addition, the Italian requirements specifications need to be complemented with conformity evaluation specifications analogous to the European DSRC and EFC standards[6] in order to provide suitable technical support for an open vendor market.

RSE regulatory RF and DSRC issues

Regulatory issues described in this paragraph are only related to the **RSE** part of the Telepass specifications.

UNI-10607 standard [UNI DSRC] does not comply with the European spectral requirements, as it infringes the frequency band requirements (see also Annex D).

The UNI-10607 [UNI DSRC] standard does not comply with the maximum allowed radiated power restrictions, in that +33 dBm EIRP is permitted, whereas the UNI-10607 allows up to +39 dBm.

Therefore, as known, installation of "UNI-10607 compliant RSEs" throughout Europe would not be compliant with the European RF regulations, as the technology infringes European

[6] [ETSI DSRC] aligned with the [R&TTE], and [EFC AID Tests]

spectral requirements. It is to be noted that Italy has a CEN A-deviation which allows widespread national operation of the Telepass system.

The effect of the Telepass' non-compliance with the European-wide regulations is not only a formal issue but also raises concern that performance would be affected, due to interference[7], if Telepass and European standard DSRC 5.8 GHz RSEs were to operate in the same charging point. The interference is likely to be manageable in a single lane environment (e.g. through usage of time division multiple access based technique), where a major design difficulty is the seamless integration of a "dual RSE protocol" into the existing RSEs (i.e. ensuring the quality of service to existing users, traffic safety and traffic flow). The interference is likely to be very challenging to solve in a free flow multilane charging point environment.

Conclusions

- The identified issues above need to be resolved if the Italian specifications [UNI DSRC, UNI AID] are to provide a suitable technical basis for an open vendor market of Telepass compliant equipment. The Italian specifications are currently being updated according to the results of this analysis. It is expected that the revised Italian specifications will be assessed and this report updated accordingly before June 2005.
- A complete description of the EFC functionality supported by and operational constraints associated with the Telepass application is lacking.
- Installation of RSE according to the UNI-10607 standard [UNI DSRC] throughout Europe would not be compliant with the European RF regulations as they infringe bandwidth restrictions.
- Compatibility issues between the European and Italian DSRC for non-detrimental coexistence of RSEs or dual mode RSEs ought to be clarified[8]. It is likely that the interference can be technically managed in a single lane environment, but it would have a high operational impact on 23 interconnected Concessionaires.
- Relevant actions related to spectrum management regulatory constraints on a European level need to be identified and pursued, if the Telepass RSE technology was deemed suitable as part of the EETS or for adoption on a European-wide level.
- The ETSI standard associated with Telepass [ETSI UNI], including the unwanted emission and spurious emission limits, probably needs updating to reflect the R&TTE Directive [RTTE].

4 Technical interoperability using DSRC at 5.8 GHz

4.1 What it means

EFC interoperability, using DSRC at 5.8 GHz, on a technical and procedural level involves both the DSRC protocol and the EFC application itself. Focusing on the interface between the OBU and the RSE - the most crucial interface concerning interoperability between existing DSRC-systems in Europe - both the DSRC and EFC application should be taken into account when defining the EETS using DSRC at 5.8 GHz.

[7] The "Italian" downlink is likely to interfere with the "CEN" uplink.

[8] OBU wake-up behaviour and protocol selection mechanism.

Figure 1 schematically shows the OBU and the RSE having the two principal functions:

- communication via DSRC
- execution of the EFC application.

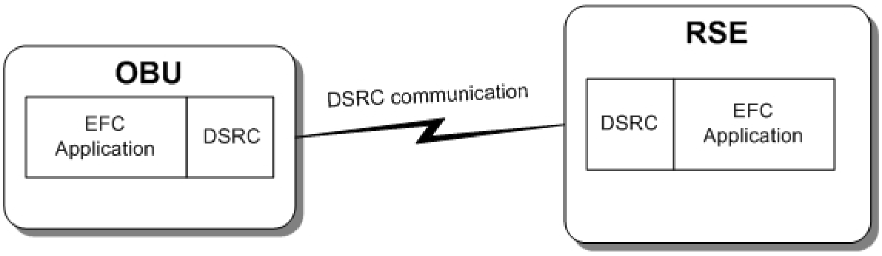


Figure 1: DSRC communication and EFC application

An EFC application[9] is specified by a set of functions, file structures, data elements and the security architecture. The building blocks for the EFC application are found in the EFC application interface standard known as “14906” [EFC AID]. However, EFC applications could be very different. The tariff-setting principles often differ from one system to another and this is one of the main reasons for the differences, e.g for the classification parameters used and how the fee is calculated. The security architecture is also one of the main reasons for the differences, e.g. access to data stored in the OBU and the different security mechanisms to protect the integrity of the data. Hence, interoperability is not guaranteed although EFC applications are build on the same standard.

Technical interoperability is achieved if the OBU and RSE use the same DSRC parameters profiles (i.e. parameter settings) and the same EFC application.

4.2 Approaches to interoperability

There are two main EFC 5.8 GHz technologies that are deployed in Europe, one according to the European CEN standards and the other one according to the UNI-10607 standard.

A key issue to decide when designing the technical concept for interoperability is whether it is more effective:

- to update the RSEs providing them with additional application and communication capabilities to handle the existing and mixed population of OBUs, or
- to define a new “enhanced” OBU that is supported by all existing RSEs in Europe, or
- to agree on a common European solution, based on the CEN standards, that is associated with the ETTS that should be supported by all RSEs in Europe, not precluding the OBUs and RSEs to support additional services locally at their own discretion.

It is of course also possible to combine the approaches above. EG1 address this issue in its investigation of suitable concepts (see sections 5 and 6).

4.3 Guiding principles

EG1 adopted the following guiding principles as the basis for the elaboration of the investigated concepts, which are discussed in the following sections:

[9] It is common to use the term "EFC application" to describe the OBU EFC application resources (set of functions, file structures and data). Note that the term is sometimes used to describe the execution of the operational procedures and actions that are under the discretion of the Operator / RSE ("master-slave concept").

- The principles of the interoperable electronic toll service (EETS) as defined in Directive 2004/52/EC.
- The DSRC 5.8 GHz transaction for EFC charging associated with the EETS is based on central account charging.
- Each Member State, and/or operator remains free to define tariff and local vehicle classes (i.e. the subsidiarity principle). The OBU shall contain the minimum set of vehicle characteristics as defined in Expert Group 2's final report [EG2 Final Report].
- Local and national charging schemes are permitted to continue alongside the EETS. Additional (toll) services and features may be offered by the Operators, at their own discretion, on the OBU as long as these do not compromise the EETS (i.e. the subsidiarity principle).
- All users, whatever their country of origin, must be treated equally within a Member State. This is an essential requirement contained in the European Treaty.
- Users are free to take advantage of the local and/or European service, i.e. subscribing to the EETS remains a voluntary act for the "clients".
- The EETS service should be cost-effective to introduce, operate and maintain.
- The EETS ensures data integrity, authentication and access protection of sensitive user data suitable for a European multi-operator environment

5 Concepts

5.1 Introduction

Section 5 outlines the four distinct alternatives concepts for allocation of interoperability capabilities between the OBU and RSE. The concepts are first introduced by brief scenario descriptions. The main assumptions, consequences and open issues associated with the concepts are thereafter summarised.

The four concepts are:

1. **Common DSRC stack and EFC application**[10] supported by all eligible on-board units (OBUs) and roadside equipment (RSE).
2. **Multi-protocol OBU (CEN, Telepass, …)**: more than one DSRC stack or/and EFC application supported by the OBU, e.g. "Dual DSRC stacks (CEN and Telepass) / Common EFC application (e.g. CARDME)" and "Dual DSRC stacks (CEN and Telepass) / several EFC applications (French TIS, Spanish Via T, Portuguese Via Verde, Telepass …)"
3. **Multi-protocol RSE (CEN, Telepass, …)**: more than one DSRC stack and one or more EFC applications supported by the RSE, e.g. Dual DSRC stacks (CEN and Telepass) / several EFC applications (French TIS, Portuguese Via Verde, Telepass …)
4. **Dynamically configurable OBU**: the "EFC application" is downloaded, e.g. via another technology like GPRS, whenever "entering" a new EFC domain

Combinations of these four basic concepts are possible but are not explicitly discussed as the purpose of this examination is to investigate the main principles of the EETS at 5.8 GHz.

[10] The term "EFC application" is used, as customary, to describe the OBU EFC application resources (set of functions, file structures and data). Note that the term is sometimes used to describe the execution of the operational procedures and actions that are under the discretion of the Operator / RSE ("master-slave concept").

5.2 Common DSRC stack and EFC application

Figure 2 shows the scenario where a common European DSRC stack and EFC application has been agreed. The European DSRC stack and EFC application (Eur DSRC/EFC) shall be supported by any European EFC system independent of the other DSRC stacks and EFC applications implemented in the EFC system. A user who buys an OBU with just the European DSRC and EFC application shall be supported wherever he goes. This implies that the European OBU concept could also be used for local and national interoperable EFC schemes.

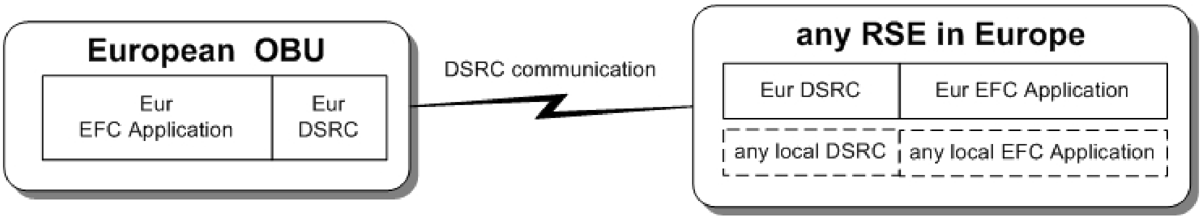


Figure 2: Common DSRC stack and EFC application

5.3 Multi-protocol OBU

General concept

Figure 3 shows the scenario where the OBU has more than one DSRC stack or/and EFC application.

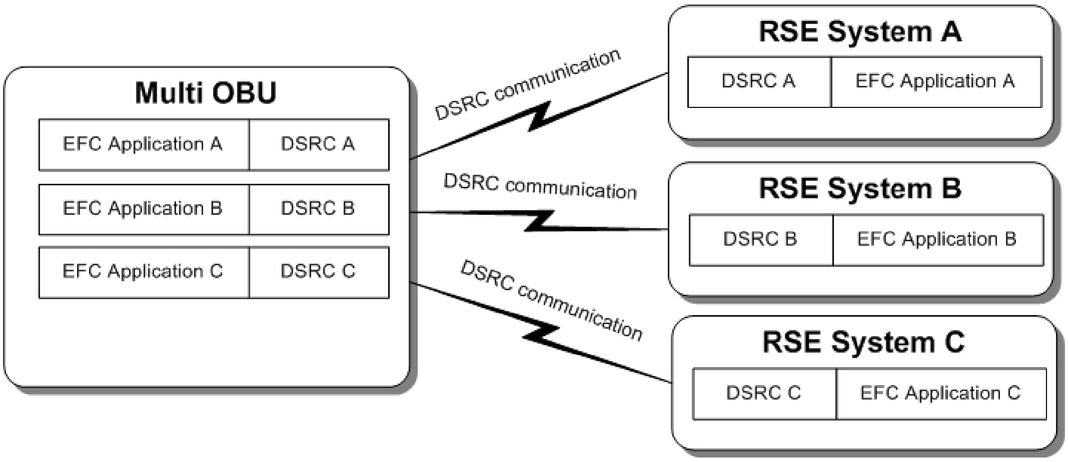


Figure 3: The Multi-protocol OBU with two or more DSRC stacks and EFC applications

The RSE will select which DSRC stack and EFC application to use as part of the DSRC / EFC initialisation with the OBU, which takes place when the OBU enters into the DSRC communication zone.

Two specific variants of the multi-protocol OBU are described below.

2a) Dual DSRC stacks / Common EFC application

This specific variant of the multi-protocol OBU has two different DSRC stacks and one common EFC application.

EXAMPLE

Figure 4 shows an example of an OBU with Dual DSRC stacks (CEN and Telepass) and a common EFC application, for instance based on the CARDME / PISTA transaction.

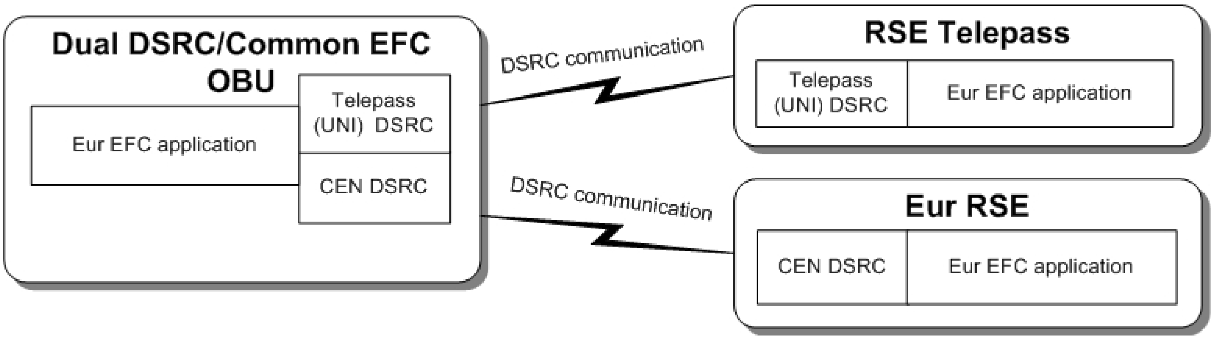


Figure 4: Dual DSRC stacks / common EFC – an example of a multi-protocol OBU

2b) Dual DSRC stacks / Dual EFC applications

This specific variant of the multi-protocol OBU has two DSRC stacks and two EFC applications.

EXAMPLE

A “Telepass Dual Mode OBU" is an example of a "Dual DSRC stacks / Dual EFC applications" OBU, see Figure 5. It supports the Telepass DSRC and the Telepass EFC application as well as a DSRC according to CEN and an EFC application, for instance based on the CARDME / PISTA transaction.

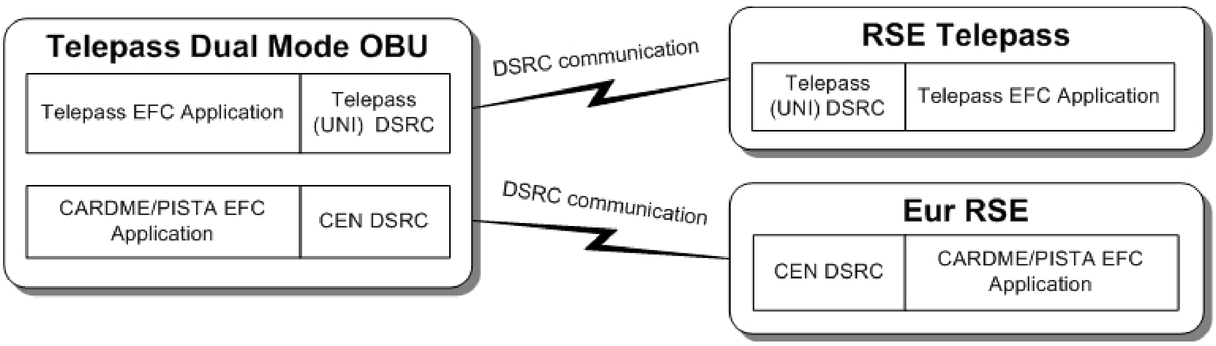


Figure 5: “Telepass” Dual Mode OBU – an example of a multi-protocol OBU

5.4 Multi-protocol RSE

Figure 6 shows the scenario with a multi-protocol RSE where the RSE has more than one DSRC stack and EFC application.

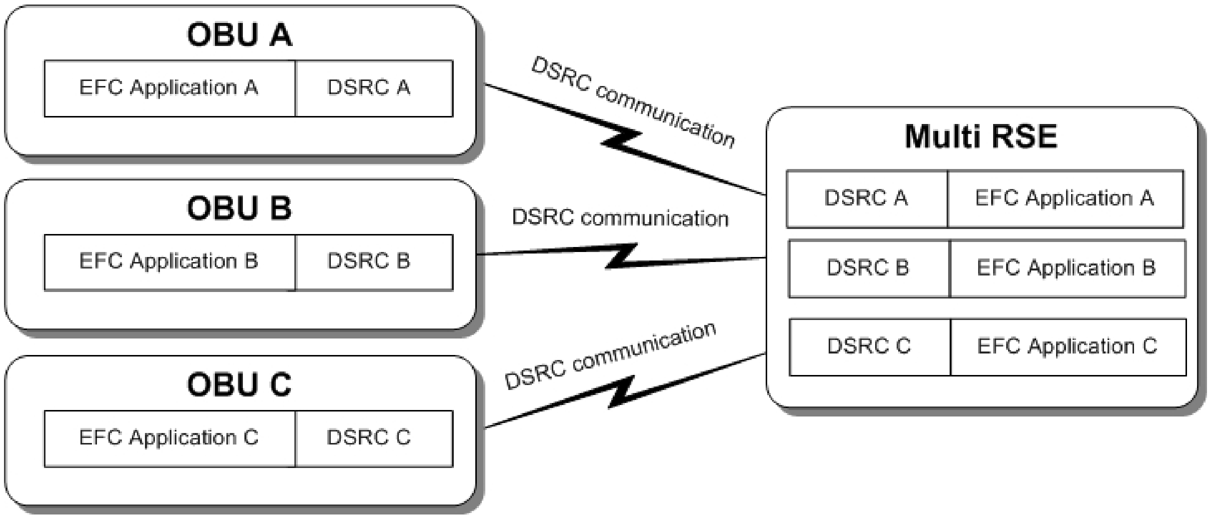


Figure 6: The Multi-protocol RSE with more than one DSRC stack or/and EFC application

EXAMPLE

Figure 7 shows an example where the Multi RSE supports both the Telepass and CEN DSRC stacks. It also supports the Telepass EFC application as well as the CARDME/PISTA EFC application. Hence, the Multi-protocol RSE is able to charge fee from users equipped with a Telepass OBU or "CEN DSRC and CARDME PISTA EFC application" OBU (referred to as OBU A in the figure below).

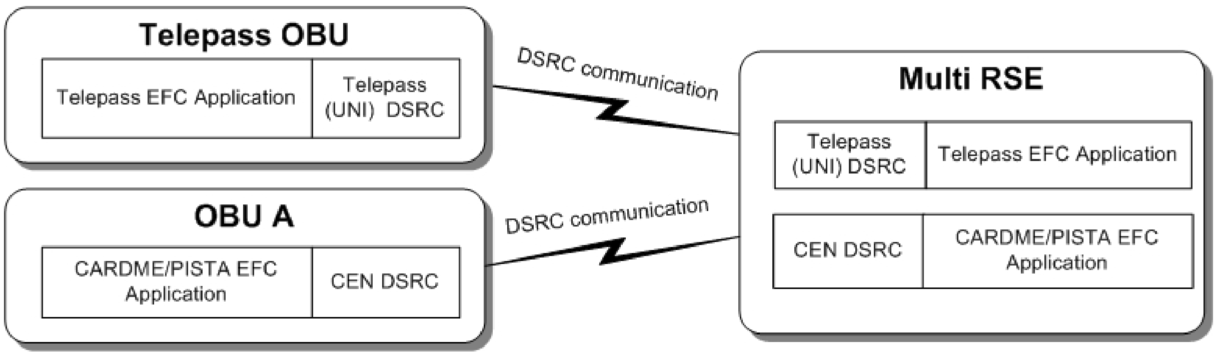


Figure 7: Multi RSE protocol – an example

5.5 Dynamically configurable OBU

The dynamically configurable OBU is able to download the EFC application whenever it enters a new EFC domain. The "EFC applications" are downloaded from download stations separate from the RSE at the charging point. The download stations could e.g. be another RSE upstream of the charging RSE, or a download point at the border between two EFC systems or "located centrally" and communication via e.g. GPRS.

It is also assumed that there is a European Download Application that is used whenever downloading the EFC application. The Download Application enables an effective and secure downloading of any EFC application in any European EFC system.

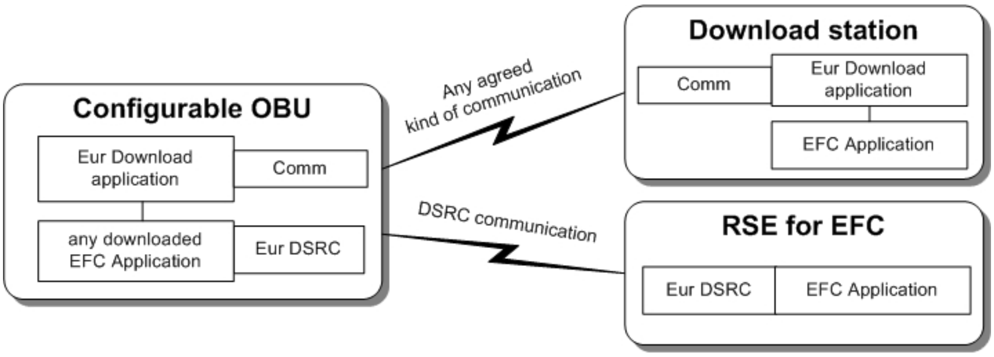


Figure 8: The configurable OBU with the Eur DSRC and Download Application

Figure 8 shows the principle of the configurable OBU. Before an OBU could be used for EFC it has to download the required EFC application in a download station ahead of the EFC RSE. Downloading is performed using any agreed kind of communication..

EXAMPLE

Figure 9 shows an example of a configurable OBU with two DSRC stacks (CEN and Telepass).

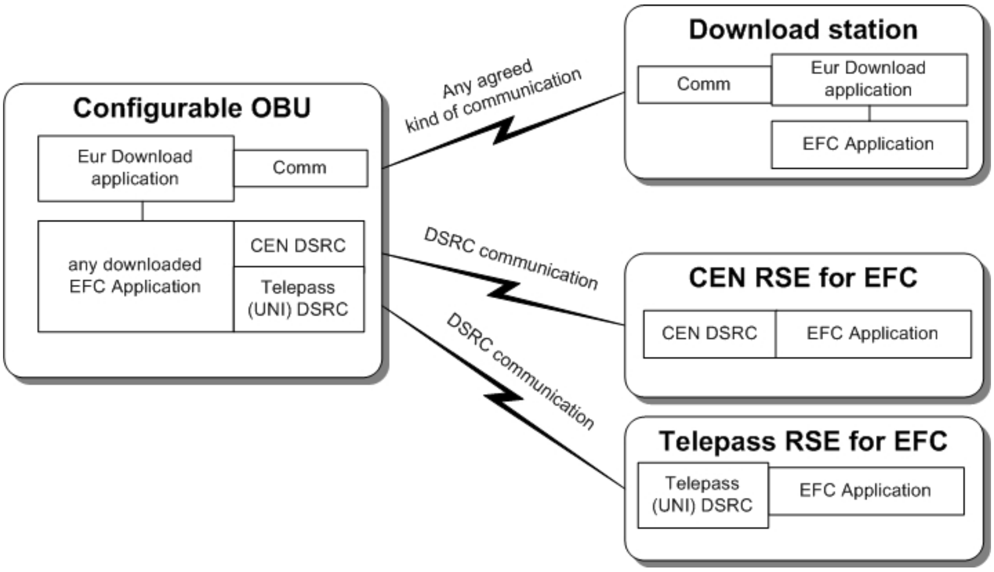


Figure 9: The configurable OBU with two DSRC stacks – an example

5.6 Summary

Item	Common DSRC stack and EFC application	Dual DSRC stacks / Common EFC application (2a)	Dual DSRC stacks / Dual EFC applications (2b)	Multi-protocol RSE	Dynamically configurable OBU
Assumptions	OBU: common DSRC stack and EFC application RSE: common DSRC stack and EFC application	OBU: Dual DSRC stacks (CEN + UNI-10607) / Common EFC application (e.g. CARDME) RSE: one of the OBU's DSRC stack + Common EFC application	OBU: Dual DSRC stacks (CEN + UNI-10607) / Dual EFC applications (e.g. CARDME + UNI-10607) RSE: one of the OBU's protocols (DSRC stack + EFC application)	OBU: one of the RSE's protocols (DSRC stack + EFC application) RSE: multiple-DSRC stack or/and EFC applications	Different EFC applications in Europe OBU: dynamically configurable OBU, dual DSRC stacks (CEN and UNI-10607) RSE: "local" EFC application and one DSRC stack (CEN or UNI-10607)
Consequences User	• New OBU or re-personalise existing OBU	• New OBU	• New OBU	• Use old (local) OBU	• New dynamically configurable OBU
Consequences OBU	• Support the common DSRC stack and the EFC application through a new OBU or re-personalisation	• Support the common EFC application and dual DSRC technologies	• Support dual DSRC stacks and dual EFC applications	• No impact	• Support the common European DSRC • Have the required (hardware and software) features to support secure dynamic configurability
Consequences RSE	• Implement the common DSRC stack and the EFC application • Adaptations. Major adaptations in Italy (dual DSRC stack and EFC applications).	• Implement the common EFC application • Adaptations.	• No adaptation concerning the DSRC and EFC	• Major adaptations in all systems • RSEs have to be provided with different DSRC and EFC applications. Implementation of further EFC applications is easier at RSE than in OBU	• Major adaptations in all systems
Consequences EFC Operator / OBU Issuer	• Issuer: offer common DSRC stack and EFC application • Secure handling and use of associated security keys • EFC Operator: implementation of common DSRC stack and EFC application	• Issuer: offer dual DSRC stacks and common EFC application • Secure handling and use of associated security keys • EFC Operator: implementation of common DSRC stack and EFC application	• Proliferation. Each of the DSCR and EFC applications has to be personalised, requiring new equipment and adaptation of procedures (incl. maintenance). • Issuer: Secure handling and use of associated security keys (note: separate keys for each application) • EFC Operator: implementation of the dual DSRC stacks and EFC applications	• Proliferation. Each DSRC EFC versions (incl. security keys) needs to be distributed and maintained • Management of various and divergent requirements on EFC applications • EFC Operator: Secure handling and use of associated security keys (note: separate keys for each application). Implementation of multi-protocol RSE	• "Local" EFC application can be used • Stations for downloading of the configuration data or /and functions. • Secure handling and use of associated security keys. Suitable physical, logical and security infrastructure has to be implemented to support the download stations.
Open Issues	• Agreement on a common DSRC stack and EFC application. • Italy: Interference between CEN and UNI-10607 DSRC RSEs when operated in proximity	• Agreement on a common EFC application. • "Dual OBU DSRC stack issues "	• Agreement on the dual EFC applications. • "Dual OBU DSRC stack issues " • Supported functionality and operational constraints associated with the Telepass service	• Performance in a multi-lane environment with a mixed population of OBUs • "RSE UNI-10607 issues" o European spectral regulations o Interference between CEN and UNI-10607 DSRC when operated in a multilane environment o Supported functionality and operational constraints associated with the Telepass service	• Agreement on the downloading concept, including details of "What" to download (software, configuration, application data etc), size constraints and obligations of the user and the operator(s) • OBU hardware and software requirements (including user memory, interpreter vs. virtual machine code) • The (security) downloading protocol • Accreditation of downloadable data / functions

Table 1: Summary of main assumptions, consequences and open issues associated with the four concepts

6 Analyses

6.1 Introduction

Section 5 outlined the four distinct concepts, and the associated main assumptions, properties and open issues.

This section reports on the qualitative analyses of the concepts and the overall recommendations. First the following concepts are evaluated from a technical and operational point of view:

1. Common DSRC stack and EFC application
2a. Dual DSRC stacks (CEN and UNI-10607) / Common EFC application
2b. Dual DSRC stacks (CEN and UNI-10607) / Dual EFC applications (one based on the CARDME / PISTA transaction and the other according to the UNI-10607 EFC application)
3. Multi-protocol RSE
4. Dynamically configurable OBU using e.g. GPRS for downloading of the "EFC application"

Subsequently, the financial impact is evaluated for the concepts that are deemed viable from a technical and operational point of view.

The methodology, models, scores and associated rationale are explained in Annex E.

6.2 Operational and technical evaluation

The analysis is built around the so-called "Qualitative Evaluation Model" where the different concepts are compared with one another. Different parameters are assigned weights and values, and are motivated by a rationale.

The first comparison level is a class of parameters, representing a major aspect of an EFC system:

- **Engineering**: Technological aspects associated with concept, such as requirements, design, implementation, development, etc. It intends to evaluate the pre-operational issues. The concepts are evaluated considering the needs of both the operators (road system design, flexibility to change and evolve) and users (restrictions, usability, and commodity). In addition, and with a technical view, the full cycle of the deployment is considered: design, conformity, production, installation and flexibility to evolve.
- **Operation and Maintenance**: Operational aspects associated with concept, from the installation and setup to the daily operation. In addition other relevant aspects, like performance and maintainability, are also considered.
- **Migration effort**: The ability of the concept to support smooth and graceful change, due to migration to a new generation or addition of new functionalities or intelligence, bearing in mind the accommodation of the EETS. It intends to reflect the system flexibility to be adapted, upgraded and extended. OBU marketing and dissemination is also considered.

Each class has been assigned similar relative weights (Engineering 35%, Operations and maintenance 35% and Migration effort 30%) and is further divided in 5 parameters (the engineering class includes e.g. road system design including multilane use and certification process), that are assigned different weights (see Annex E).

Each concept is compared with all the other concepts, making all possible permutations, by evaluation of each individual parameter (score and rationale, see E.2). The latter also provide a sensitivity check of the analysis and how stable the overall analysis are against changes in the scoring of individual parameters. The sum of the analysis of the concepts and associated parameters provides an overall quantitative technical and operational evaluation. Figure 10 represents graphically the results – the higher the score the more "suitable" the concept is as the basis for the EETS at 5.8 GHz from a technical and operational point of view.

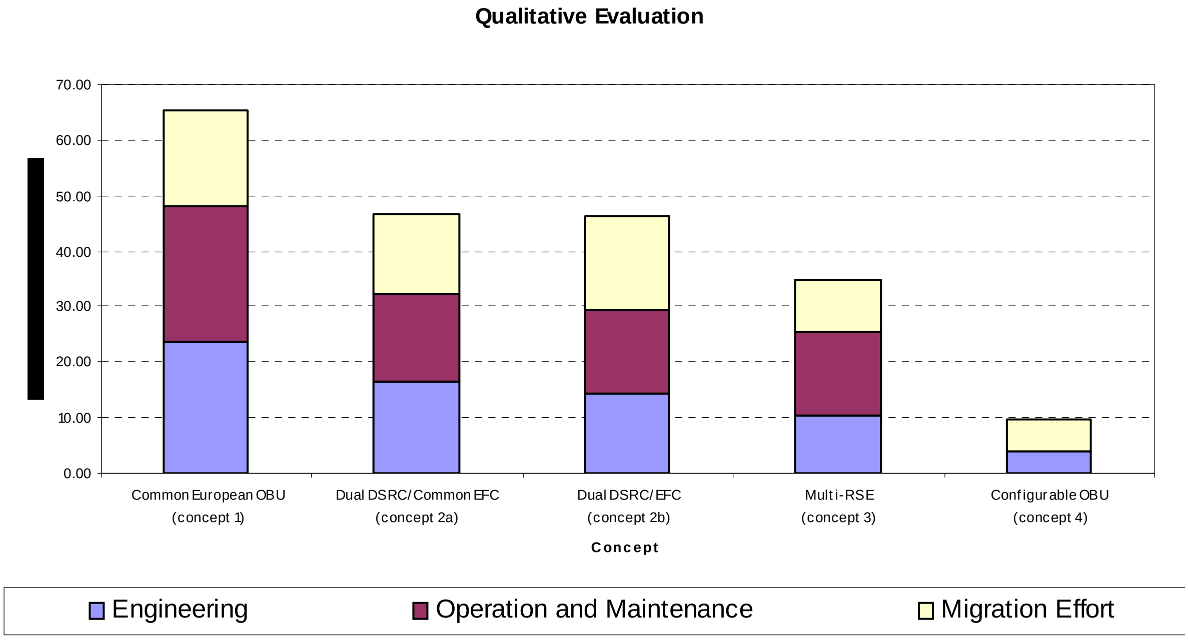


Figure 10: Summary of the quantitative technical and operational evaluation

Remarks:

- "Common DSRC stack and EFC application" (**concept 1**) appears attractive from a technical and operational point of view. It has the lowest technical complexity, is simple to operate and maintain. The concept is associated with low migration effort, except in Italy where major adaptations would be required. This technical concept represents the "ideal solution"; a single common charging transaction implemented and used all over Europe.
- "Dual DSRC stacks (CEN and UNI-10607) / Common EFC application" (**concept 2a**) also appears attractive from an operational point of view. It is also relatively simple to operate and maintain. The OBU hardware includes two DSRC stacks (as opposed to one for concept 1), which is not deemed to constitute a fundamental obstacle once the issues associated with the Telepass DSRC specifications [UNI DSRC] have been resolved. The concept is associated with low migration effort, except in Italy where significant adaptations would be required.
- "Dual DSRC stacks (CEN and UNI-10607) / Dual EFC applications" (**concept 2b**) seems a little less attractive from an operational and maintenance point of view, including the personalisation of OBUs and the secure handling of security keys. The OBU hardware includes two DSRC stacks (as opposed to one for concept 1), which is not deemed to constitute a fundamental obstacle once the issues associated with the Telepass DSRC

specifications [UNI DSRC] have been resolved. The concept is associated with a relatively low migration effort.

- Multi-protocol RSE (**concept 3**). Whereas this concept may look relatively attractive from an operational and maintenance point of view, it is associated with significant adaptations of RSE throughout Europe. It is further noted that the UNI-10607 RSE technology infringes spectral regulations (the bandwidth requirements, see also Annex D). This concept, in view of the European spectrum regulations, is not deemed suitable as part of the EETS.
- Dynamically configurable OBU (**concept 4**) using e.g. GPRS for downloading of the "EFC application". This concept appears not only technically complex (e.g. needs agreement on the downloading concept including details of “What” to download (software, configuration, application data etc), size constraints, agreement of OBU hardware and software requirements, security downloading protocol) but also seems arduous to operate (e.g. clarification of the obligations of the user and the operator(s), accreditation of downloadable data / functions etc). This concept, considering the current state-of-affairs, is not deemed mature enough to be viable for the 5.8 GHz EETS service.

6.3 Financial impact

Taking into account the results of the technical and operational evaluation, the following concepts are evaluated in terms of their financial impact:

1. Common DSRC stack and EFC application

2a. Dual DSRC stacks (CEN and UNI-10607) / Common EFC application"

2b. Dual DSRC stacks (CEN and UNI-10607) / Dual EFC applications"

The **financial evaluation is based on statistics** from the following sources:

- EC Directorate-General Energy and Transport "Statistical pocket book 2004"
- EC Directorate-General Energy and Transport "European energy and transport – Trends to 2030"
- ASECAP "Statistical Bulletin 2004"

In addition, assumptions are made regarding delta cost drivers and associated cost envelopes. The **delta cost drivers are the elements that are connected with significant cost and that are specific to the concept**. The **cost envelope** is the **estimated spread of the cost driver** ("nominal", minimum = "optimistic", maximum = pessimistic"). The assumptions accounted for below have been made when evaluating the cost impact of the examined concepts.

Common DSRC stack and EFC application (concept 1)

- Lifetime of RSE 5-7 years
- Costs focused on the RSE adaptation in Italy only, considering that the required adaptations in other countries are minor. The major hardware adaptation to be done for Portugal is not included, as the migration is currently undertaken (i.e. a sunk cost).
- Estimated number of Italian EFC lanes in 2012: 2500 lanes
- Percentage of European lanes in Italy: 50 % (nominal) (Range of 20, 80, 100 %)

- RSE adaptation costs in Italy per lane: 10.000 Euro (nominal) (range of 5.000, 12.000, 15.000 Euro)
- Development costs: 1- 2 Million Euro

Dual protocol OBU (concepts 2a and 2b)

- Development costs: 5 (manufacturers) * 1,5 M€ = 7,5 M€ in the order of 5 – 10 M€, assuming an open (chipset and) OBU vendor market
- OBU delta price (i.e. the price difference for OBUs associated with concept 2a/b compared with concept 1) assuming that free market dynamics and associated pricing apply (see also Annex J): 3 €, in the order of 1 – 5 €.
- No premature replacement: replacement only at the end of the lifetime of the old OBU
- Growth: 10 – 20 % per annum - 20 Million new OBUs (order: 10 – 40 million), including replacements, in Europe until 2015.
- European OBU adoption rate (i.e. ratio of OBU that supports the EETS at 5.8 GHz compared with all new OBUs issued in Europe): range of 5, 10, 20, 50, 80 %.
- RSE adaptations for the two sub-variants:
  - Dual DSRC stacks (CEN and UNI-10607) / Common EFC application" (**concept 2a**): RSE adaptations for the Common European EFC application (significant for Italy): 2000 Euro more pro lane. 0.5 to 2 Million Euro in total.
  - Dual DSRC stacks (CEN and UNI-10607) / Dual EFC applications" (**concept 2b**): 0

Considering all parameters, the number of possible scenarios is considered too large for presenting a single overall view of the financial impact. In the following, two possible scenarios are presented which are associated with the following assumptions:

- All vehicles are taken into account, not simply the HGVs, in order to show overall cost differences.
- Common DSRC stack and EFC application (concept 1): 1M€ development cost and lane delta cost 10k€.
- Dual DSRC stacks (CEN and UNI-10607) / Common EFC application" (concept 2a): 5M€ development cost, 50% European OBU adoption rate, 100% of the Telepass lanes adapted, 2k€ adaptation cost per lane.
- Dual DSRC stacks (CEN and UNI-10607) / Dual EFC applications" (concept 2b): 7,5M€ development cost, 50% European OBU adoption rate.

The two scenarios differ only for the two following parameter values:

- European OBU adoption rate: Scenario 1 assumes 50%, whereas Scenario 2[11] assumes 10%.
- OBU delta price: Scenario 1 assumes 3€, whereas Scenario 2 assumes 5€.

[11] The relatively small OBU market associated with scenario 2 may not be large enough for OBU vendors to develop "EETS" products (see also Annex J).

Figure 11 graphically illustrates the results of the cost-benefit analysis for Scenario 1.

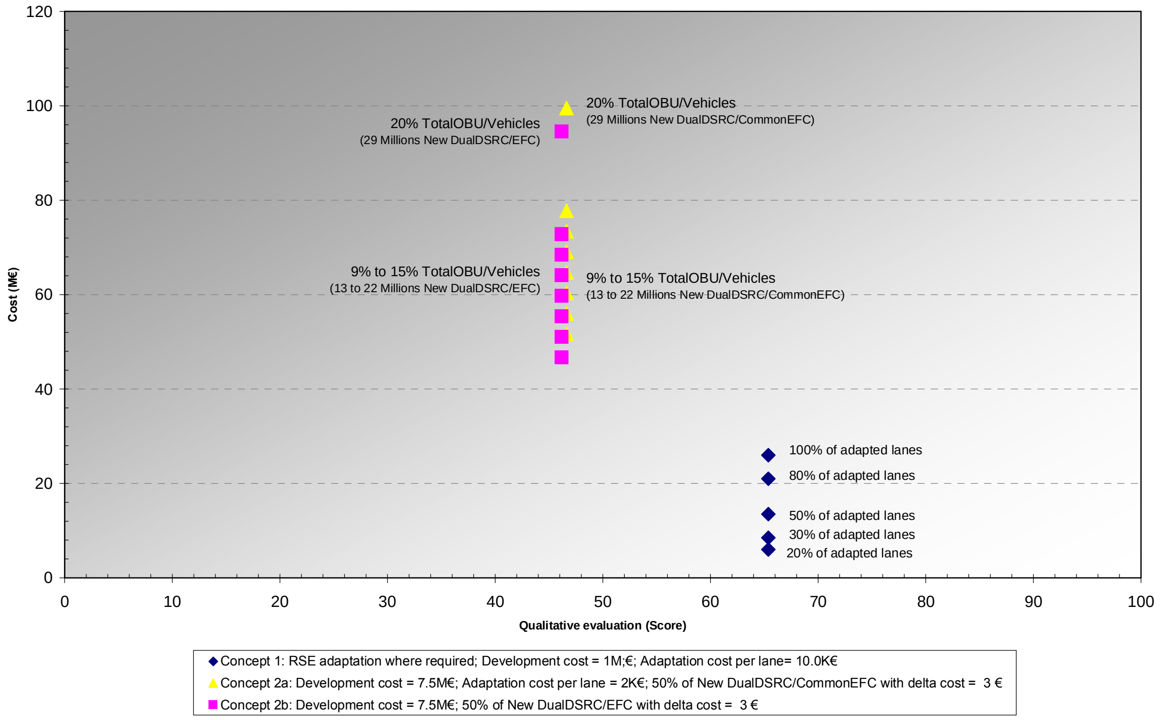


Figure 11: Cost-benefit analysis: scenario 1

Figure 12 shows the results of the cost-benefit analysis for Scenario 2.

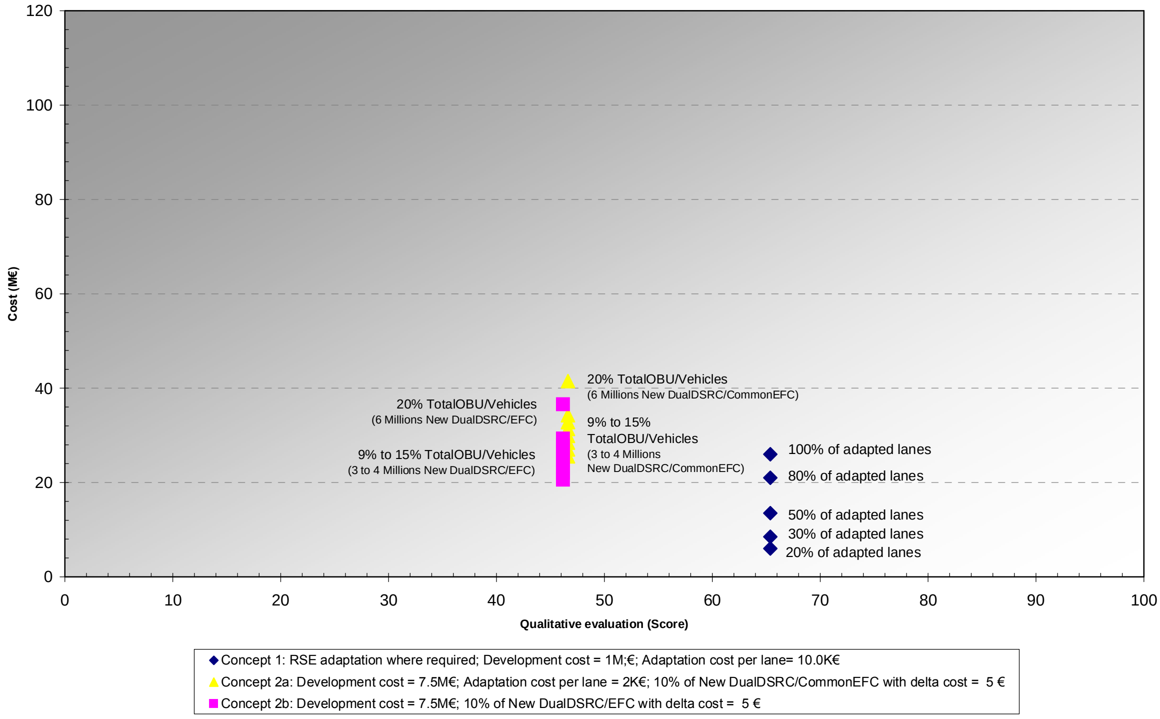


Figure 12. Cost-benefit analysis: scenario 2

Remarks

- The global cost-benefit analysis is largely influenced by the assumed estimated costs of relevant parameters. As the two examples above show, the "Common DSRC stack and EFC application (concept 1)" can be regarded as more cost-effective or not, depending on the estimated delta price associated with "Dual protocol OBUs (concepts 2a and 2b)" and on the need for interoperability among the population of vehicles using OBUs.
- As a consequence of the above findings, variation of the parameters' values affects the financial impact result (i.e. "ranking" and the relative difference of the evaluated concepts). In other words, differences between different concepts increase or decrease. This means that appropriate choice of parameters can lead to either largely diverse scoring, or rather similar ones.
- The analytical model that has been developed, however, allows identifying break-even points where a solution is more overall cost-effective than another one. In addition to that, as some of the most relevant parameters can be largely influenced by commercial and political decisions, the model can be considered as a useful tool for what-if analysis on political decisions to be taken.

6.4 Overall reflections

In the light of the study that has been conducted, the following overall reflections are offered by EG1 in addition to the remarks in 6.2-6.3:

- The guiding principles, formulated in 4.3, ought to form part of the basis of the EETS at 5.8 GHz.
- "Common DSRC stack and EFC application[12]" (**concept 1**) appears attractive, in particular from a technical and operational point of view.
- "Dual DSRC stacks (CEN and UNI-10607) / Common EFC application" (**concept 2a**) appears similarly attractive to concept 1 from an operational point of view. The OBU hardware includes two DSRC stacks (as opposed to one for concept 1), which is not deemed to constitute a fundamental obstacle once the issues associated with the Telepass DSRC specifications [UNI DSRC] have been resolved and if a fair (chipset and OBU) vendor market can be ensured.
- "Dual DSRC stacks (CEN and UNI-10607) / Dual EFC applications" (**concept 2b**) seems less attractive from an operational and maintenance point of view, including the personalisation of OBUs and the secure handling of security keys. This concept is associated with a relatively small migration effort. The OBU hardware includes two DSRC stacks (as opposed to one for concept 1), which is not deemed to constitute a fundamental obstacle (see also concept 2a above). It may prove more difficult to agree on two EFC applications than one common, as it is likely to be challenging to agree on the (criteria for) selection of the CEN EFC application in view of the currently deployed EFC applications (French TIS, Portuguese Via Verde, Spanish Via T etc). Supporting all deployed EFC applications are not considered viable due to the cost and complexity of operating such a "proliferated" EETS.

[12] The term "EFC application" is used, as customary, to describe the OBU EFC application resources (set of functions, file structures and data). Note that the term is sometimes used to describe the execution of the operational procedures and actions that are under the discretion of the Operator / RSE ("master-slave concept").

- Multi-protocol RSE (**concept 3**). This concept is associated with significant adaptations of RSE throughout Europe. This concept, in view of the European spectrum regulations (see Annex D), is not deemed suitable as part of the EETS or for adoption on a European-wide level.
- Dynamically configurable OBU (**concept 4**) using e.g. GPRS for downloading of the "EFC application". This concept appears not only technically but also seems arduous to operate. This concept, considering the current state-of-affairs, is not deemed mature enough to be viable for the 5.8 GHz service.

The Italian Telepass specifications [UNI DSRC, UNI AID] have been assessed with the overall aim to appraise whether they support an open vendor market of UNI-10607 compliant equipment from a technical point of view. Whereas the assess specifications are relatively complete, section 3.2 reports on ambiguities and missing information that need to be resolved in order to ensure equipment compatibility and an appropriate technical support for an open vendor market in the same way as the CEN standards [CEN DSRC, CEN EFC] do. It should be noted that the Italian specifications [UNI DSRC, UNI AID] are being updated (also as a consequences of this analysis), at the time of writing of this report, with the aim to provide a completed set of specifications and to resolve the identified issues. It is expected that the revised Italian UNI-10607 specifications will be re-examined before June 2005. One should consider accelerating the completion of UNI-10607 by use of a dedicated team of experts, should there be a need to continue the revision beyond June 2005.

A common EFC application may be based on the on-going CEN work (which will be based on the results of the European projects CARDME, PISTA and CESARE, see Annex G) on

- Minimum Interoperable Specification for DSRC-EFC transactions,
- Conformity evaluation of OBU and RSE to "DSRC-MIS EFC application transaction requirements”

Further, the EC funded Road Charging Interoperability (RCI) project, in which key stakeholders (including operators) will define and test an interoperability platform for present and future EFC systems, should further drive the development of the EETS and the EETS-compliant equipment.

Finally, EG1 recommends the following future work to be undertaken (regardless of retained concept) to develop the EETS at 5.8 GHz

- Competitive and fair EETS business model, including conditions and measures that aim to ensure that the "EETS (5.8 GHz) specification" have no discriminatory effect
- Security framework including key management
- Technical specification of the EETS at 5.8 GHz, e.g. through referencing to the appropriate standards / specifications, after agreement on the principles and the concept that form the basis for such a service specification
- OBU distribution

ANNEX A – MEMBERS OF EXPERT GROUP 1

The members of Expert Group 1 were appointed by the European Commission.

Name	**Company / Organisation**
Jesper Engdahl (Lead)	Rapp Trans (Switzerland)
Jorge Conçalves	Via Verde / BRISA (Portugal)
Trond Foss	SINTEF (Norway)
Paolo Giorgi	Autostrade per l'Italia (Italy)
Bernard Lamy	CSSI (France)
Wilhelm Melchers	TÜV Rheinland Group (Germany)

ANNEX B – GLOSSARY OF TERMS

ASFA	Federation of French motorway and toll facility companies (Association des Sociétés Françaises d'Autoroutes, www.autoroutes.fr)
CARDME	Concerted Action for Research on Demand Management in Europe
CEN	European Committee for Standardization (Comité Européen de Normalisation, www.cenorm.be)
DSRC	Dedicated Short-Range Communication
EETS	European Electronic Toll Service
EIRP	Emitted Isotropically Radiated Power
EFC	Electronic Fee Collection
EG1	Expert Group 1 (on microwave technologies at 5.8 GHz)
ETSI	European Telecommunications Standards Institute (www.etsi.org)
GNSS/CN	Global Navigation and Satellite System / Cellular Network (sometimes referred to as GPS/GSM)
GSS	Global Specification for Short Range Communication
HMC&E	Her Majesty's Customs and Excise
HGV	Heavy Goods Vehicle
ISO	International Standards Organisation (www.iso.ch)
L1	Layer 1 of DSRC (Physical Layer)
L2	Layer 2 of DSRC (Data Link Layer)
L7	Layer 7 of DSRC (Application Layer)
MEDIA	Management of Efc Dsrc Interoperability in the Alpine region
MMI	Man-Machine Interface
NORITS	Nordic Interoperability for Tolling Systems
NPRA	Norwegian Public Road Administration (www.vegvesen.no)
OBU	On-Board Unit
PISTA	Pilot on Interoperable Systems for Tolling Applications
RSE	Road-Side Equipment
TfL	Transport for London

ANNEX C – REFERENCE LISTS

Reference	Document no	Date	Document title
[CEN DSRC]	EN 12253	2004	Road Transport and Traffic Telematics (RTTT) – Dedicated Short-Range Communication (DSRC) – Physical layer using microwave at 5.8 GHz
	EN 12795	2002	Road Transport and Traffic Telematics (RTTT) – Dedicated Short-Range Communication (DSRC) – Medium access and logical link control
	EN 12834	2002	Road Transport and Traffic Telematics (RTTT) – Dedicated Short-Range Communication (DSRC) – Application Layer
	EN 13372	2004	Road Transport and Traffic Telematics (RTTT) – Dedicated Short-Range Communication (DSRC) – DSRC profiles for RTTT applications
[EFC AID]	EN ISO 14906	2004	Road Traffic and Transport Telematics (RTTT) – Electronic Fee Collection – Application interface definition for dedicated short range communication
[EFC AID Tests]	CEN ISO/TS 14907-2	2005	Road Traffic and Transport Telematics (RTTT) – Electronic Fee Collection – OBU conformance test procedures
[ETSI DSRC]	EN 300 674-1	2003-12	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Road Transport and Traffic Telematics (RTTT) - Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band - Part 1: General characteristics and test methods for RSU and OBU (V1.2.1)
	EN 300 674-2-1	2003-12	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Road Transport and Traffic Telematics (RTTT) - Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band - Part 2-1: Harmonised EN for the RSU under article 3.2 of the R&TTE Directive (V1.2.1)
	EN 300 674-2-2	2003-12	Electromagnetic compatibility and Radio spectrum Matters (ERM) - Road Transport and Traffic Telematics (RTTT) - Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band - Part 2-2: Harmonised EN for the OBU under article 3.2 of the R&TTE Directive (V1.2.1)
[R&TTE]	Directive 1999/5/EC	1999-03-09	Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity
[CEN EFC]	CEN/TC278 N1701	2004-12-22	Resolution by correspondence TC 278/C11/2004: New work item: Road transport and traffic telematics – Electronic fee collection (EFC) - Minimum Interoperable Specification for DSRC-EFC transactions (www.nen.nl/cen278/n1701.pdf)
	CEN/TC278 N1702	2004-12-22	Resolution by correspondence TC 278/C12/2004: New work item: Road transport and traffic telematics – Electronic fee collection (EFC) - Conformity evaluation of onboard unit and roadside equipment to "DSRC-MIS EFC application transaction requirements" (**www.nen.nl/cen278/n1702.pdf**)
[ERC]	ERC Rec 70-03	Feb 2004	ERC recommendation 70-03 relating to the use of Short Range Devices (Annex 5)
[UNI DSRC]	CEN/TC278 N1609		Draft CEN TR 00278xxx-1 RTTT – Multi-standard automatic dynamic debiting systems and automatic access control systems using DSRC at 5,8 GHz - Part 1: Physical layer (www.nen.nl/cen278/n1609.pdf)
	CEN/TC278 N1611		Draft CEN TR 00278xxx-2 RTTT – Multi-standard automatic dynamic debiting systems and automatic access control systems using DSRC at 5,8 GHz - Part 2: Data link layer (www.nen.nl/cen278/n1611.pdf)
	CEN/TC278 N1613		Draft CEN TR 00278xxx-3 RTTT – Multi-standard automatic dynamic debiting systems and automatic access control systems using DSRC at 5,8 GHz - Part 3: Application layer common service elements (www.nen.nl/cen278/n1613.pdf)
[UNI AID]	CEN/TC278 N1615		Draft CEN TR 00278xxx-4 RTTT – Multi-standard automatic dynamic debiting systems and automatic access control systems using DSRC at 5,8 GHz - Part 4: Application layer EFC application service objects (www.nen.nl/cen278/n1615.pdf)
[ETSI UNI]	ETS 200 674		Electromagnetic compatibility and Radio spectrum Matters (ERM) - Road Transport and Traffic Telematics (RTTT) - Dedicated Short Range Communication (DSRC) transmission equipment .
[Eval UNI]		2005-01-17	Expert Group 1 – Task 2 – Assessment of the Italian standards proposal specifications in view of inclusion into the European EFC service
[European Road Statistics 2004]		2004-06	European Road Statistics 2004 by ERF (www.erf.be/images/stat/ERFstats.pdf#search='European%20Road%20Statistics%202004%20by%20ERF')
[GSS]		2003	Global Specification for Short Range Communication (Kapsch TrafficCom AB, Kapsch Telecom GmbH, Thales e-Transactions CGA SA, version 3.2, 2003-08, www.etc-interop.com/pdf /gss_32.pdf)

Reference	Document no	Date	Document title
[EFC Directive]	Directive 2004/52/EC	2004-04-29	Directive 2004/52/EC of the European Parliament and the Council on the Interoperability of Electronic Road Toll Systems in the Community
[EG RTT]		Dec 1997	Report regarding designation of further frequency bands for Road Transport and Traffic Telematics, Expert Group on RTT for the European Commission DG XIII
[EG2 Final Report]		2005-02-03	Recommendations on parameters to be stored in on-board equipment designed for use with the European Electronic Toll Service Prepared by Expert Group 2: Vehicle Classification working to support the European Commission on the work on Directive 2004/52/EC (Issue 2)
[CARDME]	IST-1999-29053 Deliverable 4.1	2002	CARDME-4 – The CARDME concept (Final, 1 June 2002)
[PISTA]	IST-2000-28597 D3.4	2002-11	PISTA – Transaction Model

ANNEX D– FREQUENCY REGULATIONS, SPECTRUM AND USE

D.1 European 5.8 GHz regulations

The European Radiocommunications Committee defines the radio frequency regulations for the purpose of ensuring an effective overall use of the radio spectrum in Europe. The main constraints [ERC] related to DSRC concern (see also D.2 below):

- The maximum allowed **radiated power**: +33 dBm (corresponding to 2W)
- The **frequency band**: 10 MHz on a European basis with an additional 10 MHz sub-band on a national basis

The Radio equipment and Telecommunication Terminal Equipment [R&TTE] Directive defines the so-called essential requirements that include spectral requirements. The R&TTE Directive in its turn points to ETSI regarding DSRC [ETSI DSRC], that define the unwanted emission and spurious emission limits, for the purpose of managing interference levels. It is a pre-requisite for placing of equipment on the EU market that it fulfils the R&TTE Directive and the ETSI DSRC standard.

D.2 Frequency spectrum and use

This section is an excerpt from "Report regarding designation of further frequency bands for Road Transport and Traffic Telematics" [section 5.1 in EG RTT]. The frequency spectrum and use for the CEN and the Italian Telepass systems are sketched in the following Figures 13.a-c.

Figure 11a. CEN DSRC system

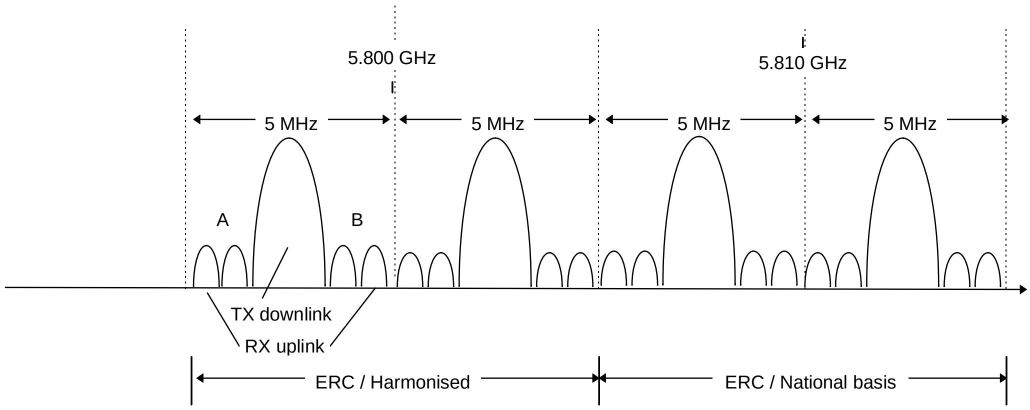


Figure 11.b. Italian system with high speed up-link

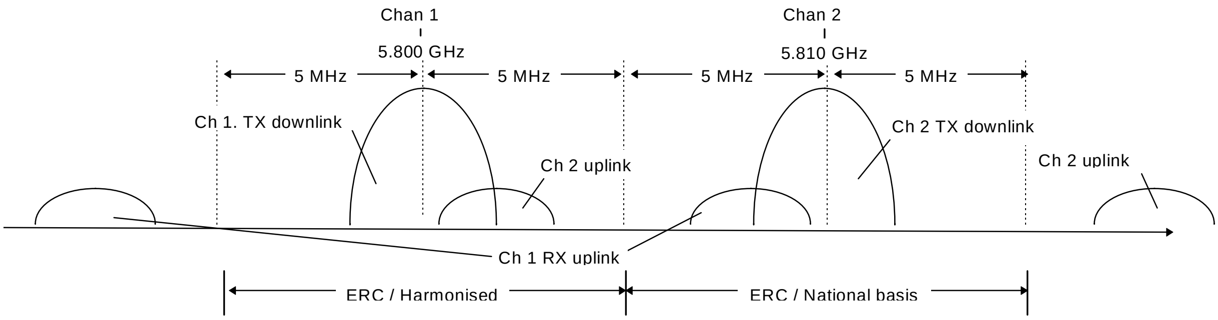
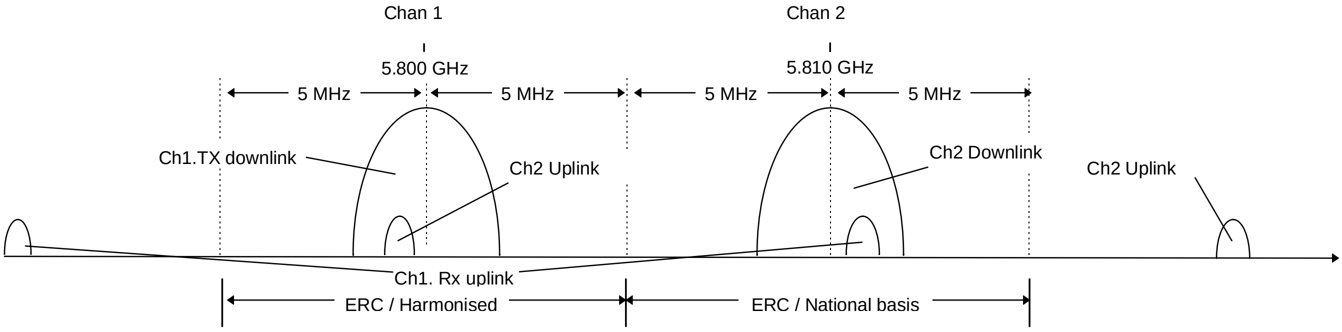


Figure 11.c. Italian system with low speed up-link



For each of the systems the transmitter and corresponding receiving bands are separated by the OBU sub carrier frequency.

The number of transceivers in a major multi-road junction can easily exceed 30 units within close proximity. Therefore, the re-use distance performance is of the highest importance. Even if the highest performance class is used the re-use distance for the same channel is 35 metres for downlink-generated interference, and up to 260 metres in exceptional uplink-to-uplink cases.

Within the 10 MHz designated on a European basis the CEN (pre-) standard uses 2 downlink channels and 4 uplink channels. The existing Italian system uses one downlink channel inside 10 MHz and two uplink channels outside the 10 MHz band available.

In connection with the development of the European DSRC (pre-) standard for RTTT applications within CEN different possibilities of achieving optimum spectrum efficiency were considered. Under the constraints of the application requirements and in the light of the available spectrum (10 MHz on a European basis and another 10 MHz on a national basis) the adopted solution was chosen.

ANNEX E– QUALITATIVE EVALUATION

E.1 Operational and technical evaluation

Section 6 addressed technical and operational impacts for the 4 distinct identified concepts. This section extends further the analysis, focusing on the system aspects and with the aim to make an overall qualitative appraisal of the concepts.

The concepts outlined in Section 5 are first evaluated in terms of engineering complexity, investment and operational costs and migration effort.

In this qualitative evaluation of the concepts, each one of them is compared against the other. In order to quantify the evaluation, a 2-level weighted comparison is used.

The first comparison level is a class of parameters, representing a major aspect of an EFC system:

- Engineering
- Operation and Maintenance
- Migration effort

Each class, in its turn, consists of set of (sub-) parameters that are described in the next sections.

Subsequently, the technical and operational viable concepts are also evaluated in terms of their financial consequences.

E.2 Qualitative Evaluation Model

Model Explanation

The analysis is built around the so-called “Qualitative Evaluation Model”, where the different concepts are compared with each others (using Excel charts), making all possible combinations.

The comparison is 2-level weighted and in the first level addresses 3 main aspects or classes: Engineering, Operation and Maintenance and Migration effort. Each class has a relative weight and the sum of the individual weights is 100.

In a second level of the analyses, each class is detailed in 5 parameters or characteristics. Again, each parameter has a relative weight and the sum of the individual weights is 100.

For the comparison of the same parameter between two systems, a grade is given according to the following criteria:

- -1 (technical scenario A worst than technical scenario B)
- 0 (technical scenario A = technical scenario B or n.a.)
- 1 (technical scenario A better than technical scenario B)

The grade is multiplied by the parameter weight and by the class weight.

Classes

- **Engineering**

  This represents the technological aspects of the architecture: requirements, design, implementation, development, etc. It intends to evaluate the pre-operational issues.

  The concepts are evaluated considering the needs of both the operators (system design, flexibility to change and evolve) and users (restrictions, usability and commodity). From the equipment side, the full cycle of the deployment is addressed: design, conformity, production, installation and flexibility to evolve.

- **Operation and Maintenance**

  This class evaluates the aspects of running the system. Operational issues are addressed, from the installation and setup to the daily operation. In addition other relevant aspects, like performance and maintainability, are considered.

- **Migration effort**

  This analyses of the system capabilities to change, due to a migration to a new generation or simple the addition of new functionalities or intelligence, having in mind the final objective of a common European EFC system. It intends to reflect the system flexibility to be adapted upgraded and extended. OBU marketing and dissemination is also considered.

Parameters

- **Engineering parameters**
  - **Road system design including multilane use**: road system requirements and specificities. Possibility and capability to fulfil the operator needs in terms of road layout, overtaking possibly limitations and constraints. Flexibility to be extended to a multilane environment.
  - **Development effort and time**: duration and difficulty of the design, prototype production and testing phases. Capability to solve technical challenges and limitations follow a specification and to be conformant with a standard or reference.
  - **Ergonomics and usability**: external OBU dimensions, aspect, shape and weight. Vehicle installation. Attractiveness to the user. Facility to use, operate and maintain.
  - **Scalability and ability to evolve**: flexibility and capability to receive new modules, functionalities, services, upgrades. Possibility to migrate or coexist with other types of architectures. Modularity.
  - **Conformity and certification process**: difficulty to specify and design according to a specification, standard or reference. Testing and certification effort.
- **Operation and maintenance parameters**
  - **TSP system operations**: system management. Work of having the system running, maintaining the specified levels of safety, efficiency, flow of traffic, data acquisition and exchange.
  - **User limitation**: constraints and restrictions of system usage, in terms of speed, safety, commodity, interface with the equipment, service and lane signalling, geographical installation, feedback. OBU maintenance. Data protection and privacy.

- **System performance**: global EFC system efficiency. Capability to fulfil pre-defined criteria in terms of transaction speed, uptime, fault tolerance, redundancy, error protection and data integrity.
- **Installation and setup**: flexibility and difficulty in installation and configuration. Adaptability to physical local characteristics. Possibility to install keeping safety and minimising traffic disturbance. Duration of installation.
- **Maintainability**: effort to fix and repair. Error prediction and detection. Equipment duration.

- **Migration effort parameters**
  - **RSE adaptations and conversion**: preparation to a future addiction or substitution of equipment or components. Capacity to be extended or upgraded. Reuse capability and equipment conversion.
  - **European harmonization**: degree of conformity with the EFC European system. Contribution to the objective of a unique and common interoperable system.
  - **Planning work**: difficulty to define the steps, methodology, tools and resources to achieve the objectives.
  - **OBU production and distribution**: constraints of a massive production and market introduction. Logistics. Price.
  - **Expected period of time for the conversion**: duration of the migration or the lifetime of the solution if not the final one or the most suitable for a simple, user friendly and cost effective common system.

Table 2-Table 11 depict the qualitative evaluation, as well as the reasoning for each parameter selection.

For each technical solution, the score of a particular class is the sum of the results of the individual parameters and the final result is the sum of the results in the three classes.

Global results are represented on Section 6.

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	Parameter	Rationale	Evaluation	Weight	Result	Parameter	Rationale	Evaluation	Weight	Result	Parameter	Rationale	Evaluation	Weight	Result	B
Concept 1 - Common DSRC stack and EFC application	Road system design incl multilane use	The Dual DSRC/EFC OBU is more complex and difficult to design	1	40%	0,140	TSP system operations		0	30%	0,000	RSE adaptations and conversion	Changes in already existing systems not necessary with the Dual DSRC/EFC OBU	-1	25%	-0,075	Concept 2b - Common DSRC stacks and dual EFC applications
	Development effort and time	Extra time and resources are necessary to design the Dual DSRC/EFC OBU	1	15%	0,053	User limitations	The Dual DSRC/EFC OBU may imply constraints in lane	1	20%	0,070	European harmonization	The Concept 1 - Common DSRC stack and EFC application is enough to achieve interoperability and no further adaptations or migration is necessary	1	25%	0,075	
	Ergonomics and usability		0	20%	0,000	System performance	The Dual DSRC/EFC OBU is more complex and several applications share the same resources	1	20%	0,070	Planning work	In existing systems the Dual DSRC/EFC OBU facilitates the migration because no major changes are necessary in RSEs	-1	15%	-0,045	
	Scalability and ability to evolve	The Dual DSRC/EFC OBU is more difficult to change due to the existence of more than one protocol	1	15%	0,053	Installation and setup		0	10%	0,000	OBU production and distribution	A Dual DSRC/EFC OBU is more complex, expensive, difficult to personalize, maintain, etc.	1	20%	0,060	
	Conformity and certification process	The Dual DSRC/EFC OBU needs more tests and verifications	1	10%	0,035	Maintainability	In the Dual DSRC/EFC OBU there are more applications to manage and maintain (additional failure points)	1	20%	0,070	Expected period of time for the conversion		0	15%	0,000	
						-1 (A worst than B)	0 (A=B or n.a.)	1 (A better than B)								

Table 2: Qualitative Evaluation Board: Concept 1 vs Concept 2b

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 1 - Common DSRC stack and EFC application	Road system design incl multilane use	No major adaptations are necessary with the Dual DSRC/Common EFC OBU	-1	40%	-0,140	TSP system operations		0	30%	0,000	RSE adaptations and conversion		0	25%	0,075	**Concept 2a - Dual DSRC stacks and common EFC application**
	Development effort and time	The Dual DSRC/Common EFC OBU is more complex, taking longer to develop	1	15%	0,053	User limitations		0	20%	0,000	European harmonization		0	25%	0,000	
	Ergonomics and usability		0	20%	0,000	System performance		0	20%	0,070	Planning work		0	15%	0,000	
	Scalability and ability to evolve		0	15%	0,000	Installation and setup		0	10%	0,000	OBU production and distribution	A Dual DSRC/Common EFC OBU is more complex, expensive, difficult to personalize, maintain, etc.	1	20%	0,060	
	Conformity and certification process	The Dual DSRC/Common EFC OBU is more complex	1	10%	0,035	Maintainability	The Dual DSRC/Common EFC OBU has additional failures points	1	20%	0,070	Expected period of time for the conversion	The Dual DSRC/Common EFC OBU decreases the conversion time	-1	15%	-0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 3: Qualitative Evaluation Board: Concept 1 vs Concept 2a

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 1 - Common DSRC stack and EFC application	Road system design incl multilane use	The Multi-protocol RSE can have more implementation specificities and restrictions (interference, reuse distance, etc.)	1	40%	0,140	TSP system operations	The overall management of the Multi-RSE requires more elaborated operations	1	30%	0,105	RSE adaptations and conversion	Road system equipment may have to be changed to introduce the Multi-RSE	1	25%	0,075	**Multi-RSE**
	Development effort and time	Extra time and resources to design the Multi-RSE solution	1	15%	0,053	User limitations	The Multi-RSE solution may impose some user restrictions like speed, lane location, etc.	1	20%	0,070	European harmonization	The European OBU is enough to achieve interoperability and no further adaptation or migration is necessary	1	25%	0,075	
	Ergonomics and usability		0	20%	0,000	System performance	In the Multi-RSE solution several applications share the same media, channel, band, resources, etc.	1	20%	0,070	Planning work	Introduction of a Multi-RSE requires a careful planning	1	15%	0,045	
	Scalability and ability to evolve	Due to the higher complexity the Multi-RSE solution is more difficult to change, upgrade, modify, adapt	1	15%	0,053	Installation and setup	The Multi-RSE is more difficult to install and tune; restrictions may apply	1	10%	0,035	OBU production and distribution	Existing OBU's can continue in use	-1	20%	-0,060	
	Conformity and certification process	The Multi-RSE needs more tests and verifications	1	10%	0,035	Maintainability	In the Multi-RSE solution there are more applications to manage and maintain (additional failure points)	1	20%	0,070	Expected period of time for the conversion	The Multi-RSE allows existing systems extended lifetime without conversion	-1	15%	-0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 4: Qualitative Evaluation Board: Concept 1 vs Concept 3

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 1 - Common DSRC stack and EFC application	Road system design incl multilane use	The Configurable OBU requires the existence of download points	1	40%	0,140	TSP system operations	In the Configurable OBU scenario it necessary to manage the download points	1	30%	0,105	RSE adaptations and conversion	Download points for the Configurable OBU solution need to be installed in existing systems to achieve interoperability	1	25%	0,075	**Configurable OBU**
	Development effort and time	The Configurable OBU is more complex and requires additional equipment for application download	1	15%	0,053	User limitations	In the Configurable OBU scenario the user may have to be aware of the application download	1	20%	0,070	European harmonization	The European OBU is enough to achieve interoperability and no further adaptation or migration is necessary	1	25%	0,075	
	Ergonomics and usability	The Configurable OBU may be larger and consume extra power	1	20%	0,070	System performance	The Configurable OBU is more complex and must execute additional operations (application loading)	1	20%	0,070	Planning work	Since it is necessary to introduce the download points, in the Configurable OBU solution there are additional steps for the migration	1	15%	0,045	
	Scalability and ability to evolve		0	15%	0,000	Installation and setup	In the Configurable OBU solution it is necessary to install and setup the download points	1	10%	0,035	OBU production and distribution	A Configurable OBU is more complex, expensive, difficult to personalize, maintain, etc.	1	20%	0,060	
	Conformity and certification process	The Configurable OBU is a more complex device and, additionally, it is necessary to test the download process and equipment	1	10%	0,035	Maintainability	In the Configurable OBU solution it is necessary to maintain the download points; additional failures points	1	20%	0,070	Expected period of time for the conversion	Both can guarantee an immediately interoperability, but the Configurable OBU solution needs a previous installation of the download points	1	15%	0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 5: Qualitative Evaluation Board: Concept 1 vs Concept 4

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 2b - Common DSRC stacks and dual EFC applications	Road system design incl multilane use	Using the Dual DSRC/Common EFC OBU, the RSEs need to be changed to support the European transaction	1	40%	0,140	TSP system operations	Using the Dual DSRC/Common EFC OBU the local application can not be used	1	30%	0,105	RSE adaptations and conversion	No adaptation in RSEs are necessary with the Dual DSRC/EFC OBU	1	25%	0,075	**Concept 2a – Dual DSRC stacks and common EFC application**
	Development effort and time	The Dual DSRC/Common EFC OBU is less complex	-1	15%	-0,053	User limitations	The Dual DSRC/EFC OBU may impose some usage restrictions	-1	20%	-0,070	European harmonization	With the Dual DSRC/Common EFC OBU only the common European EFC transaction exists	-1	25%	-0,075	
	Ergonomics and usability		0	20%	0,000	System performance	In the Dual DSRC/Common EFC OBU solution there may be an impact in transaction time (e.g. to support security)	1	20%	0,070	Planning work	In the Dual DSRC/Common EFC OBU scenario it is necessary to define the common EFC European transaction	1	15%	0,045	
	Scalability and ability to evolve		0	15%	0,000	Installation and setup		0	10%	0,035	OBU production and distribution	The security key management is more difficult in the Dual DSRC/EFC OBU solution	-1	20%	-0,060	
	Conformity and certification process	The Dual DSRC/Common EFC OBU is easier to certify	-1	10%	-0,035	Maintainability	With the Dual DSRC/Common EFC OBU there is just one transaction to maintain	-1	20%	-0,070	Expected period of time for the conversion	With the Dual DSRC/EFC OBU there is no need to worry or concern about migration	1	15%	0,045	
	-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)															

Table 6: Qualitative Evaluation Board: Concept 2b vs Concept 2a

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 2b - Dual DSRC stacks and dual EFC applications	Road system design incl multilane use	The Multi-RSE may impose some design, installation and tuning restrictions, specially in a multilane environment	1	40%	0,140	TSP system operations	The overall management of the Multi-RSE requires more elaborated operations	1	30%	0,105	RSE adaptations and conversion	In the Dual DSRC/EFC OBU scenario there are no changes in road system equipment, which may have to be changed to introduce the Multi-RSE	1	25%	0,075	**Multi-RSE**
	Development effort and time		0	15%	0,000	User limitations		0	20%	0,000	European harmonization		0	25%	0,000	
	Ergonomics and usability		0	20%	0,000	System performance	The physical resources in the Dual DSRC/EFC OBU are more limited than in the Multi-RSE	-1	20%	-0,070	Planning work	With the Multi-RSE changes in road system are more difficult to plan and execute	1	15%	0,045	
	Scalability and ability to evolve		0	15%	0,000	Installation and setup	The Multi-RSE is more difficult to install and tune; restrictions may apply	1	10%	0,035	OBU production and distribution	The Dual DSRC/EFC OBU is more complex and expensive	-1	20%	-0,060	
	Conformity and certification process	The Dual DSRC/EFC OBU is more complex than the Multi-RSE, thus more difficult to test and certify	-1	10%	-0,035	Maintainability	Failures in the Dual DSRC/EFC OBU are more difficult to identify and fix	-1	20%	-0,070	Expected period of time for the conversion	The Dual DSRC/EFC OBU allows existing systems extended lifetime without conversion	1	15%	0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 7: Qualitative Evaluation Board: Concept 2b vs Concept 3

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 2b - Dual DSRC stacks and dual EFC applications	Road system design incl multilane use	The Configurable OBU requires the existence of download points	1	40%	0,140	TSP system operations	In the Configurable OBU scenario it is necessary to manage the download points	1	30%	0,105	RSE adaptations and conversion	Download points for the Configurable OBU solution need to be installed in existing systems to achieve interoperability	1	25%	0,075	**Configurable OBU**
	Development effort and time	The Configurable OBU is more complex and requires additional equipment for application download	1	15%	0,053	User limitations	In the Configurable OBU scenario the user may have to be aware of the application download	1	20%	0,070	European harmonization	The Configurable OBU can provide the European application through a simple load operation	-1	25%	-0,075	
	Ergonomics and usability	The Configurable OBU may consume extra power	1	20%	0,070	System performance	The Configurable OBU is more complex and must execute additional operations (application loading)	1	20%	0,070	Planning work	Since it is necessary to introduce the download points, in the Configurable OBU solution there are additional steps for the migration	1	15%	0,045	
	Scalability and ability to evolve	The EFC application in the Configurable OBU is easier to change	-1	15%	-0,053	Installation and setup	In the Configurable OBU solution it is necessary to install and setup the download points	1	10%	0,035	OBU production and distribution	A Configurable OBU is more complex, expensive, difficult to personalize, maintain, etc.	1	20%	0,060	
	Conformity and certification process	The Configurable OBU is a complex device	1	10%	0,035	Maintainability		0	20%	0,000	Expected period of time for the conversion	Additionally to RSEs and OBUs, any conversion in the Configurable OBU solution requires changes in download equipment	1	15%	0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 8: Qualitative Evaluation Board: Concept 2b vs Concept 4

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	Parameter	Rationale	Evaluation	Weight	Result	Parameter	Rationale	Evaluation	Weight	Result	Parameter	Rationale	Evaluation	Weight	Result	B
Concept 2a - Dual DSRC stacks and common EFC application	Road system design incl multilane use	The Multi-RSE may impose some design, installation and tuning restrictions, specially in a multilane environment	1	40%	0,140	TSP system operations	The overall management of the Multi-RSE requires more elaborated operations	1	30%	0,105	RSE adaptations and conversion		0	25%	0,000	Multi-RSE
	Development effort and time		0	15%	0,000	User limitations		0	20%	0,000	European harmonization	Common European application	1	25%	0,000	
	Ergonomics and usability		0	20%	0,000	System performance	The physical resources in the Dual DSRC/Common EFC OBU are more limited than in the Multi-RSE	-1	20%	-0,070	Planning work	With the Multi-RSE changes in road system are more difficult to plan and execute	1	15%	0,045	
	Scalability and ability to evolve	The flexibility to change is higher in the Multi-RSE solution	-1	15%	-0,053	Installation and setup	The Multi-RSE is more difficult to install and tune; restrictions may apply	1	10%	0,035	OBU production and distribution	Dual DSRC/Common EFC OBU is more complex and expensive	-1	20%	-0,060	
	Conformity and certification process	The Dual DSRC/Common EFC OBU is more complex than the Multi-RSE, thus more difficult to test and certify	-1	10%	-0,035	Maintainability	Failures in the Dual DSRC/Common EFC OBU are more difficult to identify and fix	-1	20%	-0,070	Expected period of time for the conversion	The Dual DSRC/EFC OBU allows existing systems extended lifetime with no major conversion	1	15%	0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 9: Qualitative Evaluation Board: Concept 2a vs Concept 3

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
Concept 2a - Dual DSRC stacks and common EFC application	Road system design incl multilane use	The Configurable OBU requires the existence of download points	1	40%	0,140	TSP system operations	In the Configurable OBU scenario it is necessary to manage the download points	1	30%	0,105	RSE adaptations and conversion	Download points for the Configurable OBU solution need to be installed in existing systems to achieve interoperability	1	25%	-0,075	**Configurable OBU**
	Development effort and time	The Configurable OBU is more complex and requires additional equipment for application download	1	15%	0,053	User limitations	In the Configurable OBU scenario the user may have to be aware of the application download	1	20%	0,070	European harmonization		0	25%	-0,075	
	Ergonomics and usability	The Configurable OBU may consume extra power	1	20%	0,070	System performance	The Configurable OBU is more complex and must execute additional operations (application loading)	1	20%	0,070	Planning work	Since it is necessary to introduce the download points, in the Configurable OBU solution there are additional steps for the migration	1	15%	0,045	
	Scalability and ability to evolve	The EFC application in the Configurable OBU is easier to change	-1	15%	-0,053	Installation and setup	In the Configurable OBU solution it is necessary to install and setup the download points	1	10%	0,035	OBU production and distribution	A Configurable OBU is more complex, expensive, difficult to personalize, maintain, etc.	1	20%	0,060	
	Conformity and certification process	The Configurable OBU is a complex device	1	10%	0,035	Maintainability	In the Configurable OBU solution it is necessary to maintain the download points; additional failures points	1	20%	0,000	Expected period of time for the conversion	Additionally to RSEs and OBUs, any conversion in the Configurable OBU solution requires changes in download equipment	1	15%	0,045	

-1 (A worst than B) **0 (A=B or n.a.)** **1 (A better than B)**

Table 10: Qualitative Evaluation Board: Concept 2a vs Concept 4

	Engineering				35%	Operation and Maintenance				35%	Migration Effort				30%	
A	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**Parameter**	**Rationale**	**Evaluation**	**Weight**	**Result**	**B**
	Road system design incl multilane use	The Configurable OBU requires the existence of download points	1	40%	0,140	TSP system operations	In the Configurable OBU scenario it necessary to manage the download points	1	30%	0,105	RSE adaptations and conversion	In the Configurable OBU solution only download points need to be adapted	-1	25%	-0,075	
	Development effort and time	The Configurable OBU is more complex and requires additional equipment for application download	1	15%	0,053	User limitations	In the Configurable OBU scenario the user may have to be aware or execute the application download	1	20%	0,070	European harmonization	The Configurable OBU can provide the European application through a simple load operation	-1	25%	-0,075	
Multi-RSE	Ergonomics and usability	The Configurable OBU may be larger and consume extra power	1	20%	0,070	System performance	The Configurable OBU is more complex and must execute additional operations (application loading)	1	20%	0,070	Planning work	Since it is necessary to introduce the download points, in the Configurable OBU solution there are additional steps for the migration	1	15%	0,045	**Configurable OBU**
	Scalability and ability to evolve	The EFC application in the Configurable OBU is easier to change	-1	15%	-0,053	Installation and setup		0	10%	0,000	OBU production and distribution	The Configurable OBU is a complex and expensive device	1	20%	0,060	
	Conformity and certification process	The Configurable OBU is more complex and, additionally, it is necessary to test the download process and equipment	1	10%	0,035	Maintainability	In the Configurable OBU solution it is necessary to maintain the download points	1	20%	0,070	Expected period of time for the conversion	Additionally to RSEs and OBUs, any conversion in the Configurable OBU solution requires changes in download equipment	1	15%	0,045	

-1 (A worst than B) 0 (A=B or n.a.) 1 (A better than B)

Table 11: Qualitative Evaluation Board: Concept 3 vs Concept 4

E.3 Cost evaluation

The financial evaluation is based on statistics from the following sources (Table 12 and Table 13):

i) EC Directorate-General Energy and Transport "Statistical pocket book 2004"
ii) EC Directorate-General Energy and Transport "European energy and transport – Trends to 2030"
iii) ASECAP "Statistical Bulletin 2004"

Some data from these reports was used for preliminary calculations. In particular, a reference should be made to the method used to predict the motorization in several years in the future. Taking into account the forecasted growth in the economic activity (passengers per kilometre for public road transport and private cars and motorcycles, and tons per kilometre for trucks), it was considered that these figures would identically reflect the growth in the motorization.

Country	EC Directorate-General Energy and Transport "Statistical pocket book 2004"					ASECAP "Statistical Bulletin 2004"					
	Motorway	Passenger Cars	Buses / Coaches	Goods Vehicles	Total Vehicles	Toll Motorways	TSPs	Stations	Manual Lanes	Etc lanes	OBUs
	Year 2000	Year 2002				Year 2004					
	(Km)	Stock of vehicles (x1000)	Stock of vehicles (x1000)	Stock of vehicles (x1000)	Stock of vehicles (x1000)	Km	(x1)	(x1)	(x1)	(x1)	(x1)
BE	1.702	4.787	15	541	5.342	1	1	1	18	8	5.650
FR	9.766	29.160	87	5.903	35.150	7.896	11	524	4.269	2.300	935.000
DE	11.712	44.660	86	2.619	47.365						
IT	6.621	33.706	92	3.752	37.549	5.593	24	460	3.653	1.904	3.870.000
LU	115	287	1	23	311						
NL	2.289	6.850	11	1.027	7.889						
DK	922	1.888	14	389	2.291	34	2	2	44	12	210.000
IE	103	1.460	8	239	1.707						
UK	3.612	26.460	95	3.047	29.602						
EL	707	3.730	31	1.076	4.837	917	1	16	175	5	
PT	1.482	3.900	21	1.829	5.751	1.244	4	112	843	460	1.580.298
ES	9.049	18.730	57	409	19.196	2.612	30	204	1.790	604	
AT	1.633	3.987	9	320	4.316	2.000	5	15	109	15	275.000
FI	549	2.190	10	320	2.520						
SE	1.506	4.044	14	409	4.467						
EU15	**51.768**	**185.839**	**551**	**21.903**	**208.293**	**20.297**	**78**	**1.334**	**10.901**	**5.308**	**6.875.948**
CY	257	288	3	118	408						
CZ	517	3.647	21	350	4.018						
EE	94	401	5	80	486						
HU	448	2.530	18	400	2.948	539	2	2	32		
LV	-	619	11	103	733						
LT	417	1.180	16	106	1.301						
MT	-	205	1	50	256						
PL	399	11.028	83	2.163	13.274						
SK	296	1.330	11	171	1.512						
SI	435	914	2	60	976	381	1	21	150	89	
EU25	**54.631**	**207.980**	**724**	**25.503**	**234.207**	**21.217**	**81**	**1.357**	**11.083**	**5.397**	**6.875.948**

Country	EC Directorate-General Energy and Transport "European energy and transport – Trends to 2030"														
	Passenger Transport activity (Gpkm)										Freight Transport Activity (Gtkm)				
	Year 2000		Year 2005		Year 2010		Year 2015		Year 2020		Year 2000	Year 2005	Year 2010	Year 2015	Year 2020
	Public road transport	Private cars and Motorcycles	Public road transport	Private cars and Motorcycles	Public road transport	Private cars and Motorcycles	Public road transport	Private cars and Motorcycles	Public road transport	Private cars and Motorcycles	Trucks				
BE	12,40	107,40	12,90	110,20	12,70	114,90	13,40	124,20	14,10	135,40	32,50	36,50	41,50	45,60	49,70
FR	45,30	711,90	41,30	779,30	42,10	830,50	44,20	878,80	46,10	925,60	266,50	300,50	336,60	374,90	416,60
DE	69,00	740,1	67,70	794,5	70,50	879,60	74,60	962,20	78,3	1.042,00	347,20	405,80	463,50	520,60	579,50
IT	94,00	732,10	92,90	791,50	91,90	832,10	91,00	867,50	90,20	897,80	184,80	212,20	241,50	270,00	300,00
LU	0,90	5,10	0,90	5,60	0,90	5,80	0,90	6,00	0,90	6,30	2,40	2,80	3,70	4,30	4,80
NL	12,60	154,30	15,50	167,00	16,00	183,80	16,90	203,60	17,90	223,60	45,70	55,10	64,80	73,90	83,50
DK	11,30	67,30	11,40	71,40	11,30	74,50	11,20	76,60	11,20	77,50	17,80	19,00	20,30	21,90	24,10
IE	6,10	33,70	6,10	40,10	5,90	43,50	5,90	46,80	6,00	50,40	6,50	8,70	10,60	12,10	13,40
UK	45,00	630,00	51,00	676,30	53,50	736,00	57,30	793,10	61,20	848,70	165,80	184,00	215,90	247,80	283,20
EL	21,70	96,30	22,50	96,30	21,30	96,70	21,10	100,10	21,50	105,70	18,40	22,70	26,90	31,10	35,80
PT	11,80	93,50	11,70	102,70	11,70	112,40	11,90	122,20	12,00	131,00	20,50	23,00	27,90	33,30	39,90
ES	50,60	345,90	51,80	386,80	53,20	418,90	55,00	443,60	56,00	459,60	133,10	151,70	173,70	198,20	225,60
AT	13,10	70,90	13,00	74,70	13,10	78,50	13,80	84,20	14,60	90,80	26,30	30,60	35,30	39,80	43,80
FI	7,70	56,60	7,50	59,90	7,30	62,60	7,20	65,00	7,10	67,30	27,50	31,70	36,60	40,10	43,90
SE	11,10	93,70	11,70	96,00	11,10	96,40	11,10	99,70	11,40	105,50	32,40	39,00	44,00	49,10	53,80
EU15	**412,60**	**3.938,80**	**417,90**	**4.252,30**	**422,50**	**4.566,20**	**435,50**	**4.873,60**	**448,50**	**5.167,20**	**1.327,40**	**1.523,30**	**1.742,80**	**1.962,70**	**2.197,60**
CY	0,60	5,10	0,60	5,70	0,70	6,20	0,70	6,80	0,70	7,30	5,20	5,90	6,60	7,30	7,90
CZ	8,60	68,40	8,30	76,20	8,50	84,30	8,70	93,30	9,10	101,60	8,60	8,30	8,50	8,70	9,10
EE	2,60	6,00	2,70	6,60	2,80	7,40	2,80	8,40	2,80	9,20	4,00	6,50	7,40	8,00	8,40
HU	11,30	45,90	12,10	53,80	12,50	64,00	12,70	73,30	12,80	79,80	18,40	23,40	28,60	33,80	38,30
LV	2,40	13,80	2,50	14,80	2,60	16,80	2,60	19,80	2,60	22,20	3,60	6,30	9,00	11,40	13,20
LT	2,10	12,70	1,90	14,60	2,00	18,40	2,10	22,70	2,20	27,70	5,80	8,40	11,10	13,80	16,30
MT	0,10	2,50	0,10	2,80	0,10	3,10	0,10	3,40	0,10	3,60	3,50	3,90	4,30	4,70	5,10
PL	43,30	153,70	43,10	168,00	43,40	198,70	44,10	242,00	45,50	295,10	70,90	79,50	94,80	119,30	148,80
SK	7,80	23,30	6,90	27,90	6,40	33,90	6,50	40,70	6,70	47,40	5,00	7,70	10,30	13,50	17,30
SI	2,40	21,40	2,10	24,10	2,10	25,80	2,10	26,50	2,10	27,00	1,90	3,00	3,80	4,50	5,20
EU25	**493,80**	**4.291,60**	**498,20**	**4.646,80**	**503,60**	**5.024,80**	**517,90**	**5.410,50**	**533,10**	**5.788,10**	**1.454,30**	**1.676,20**	**1.927,20**	**2.187,70**	**2.467,20**

Table 12: Statistical data

Country	Status and Forecast calculation																									
	OBUs	Toll Motorway	Motorway	Vehicles	OBUs / Vehicles	OBUs / Vehicles	Freight Transport Activity								Passenger Transport Activity								Total Vehicles			
							Year 2005		Year 2010		Year 2015		Year 2020		Year 2005		Year 2010		Year 2015		Year 2020		Year 2005	Year 2010	Year 2015	Year 2020
	% EU25	% network EU25	% network EU25	%EU25	OBUs2004 / Vehicles2002 (%)	% Estimated 2004	Growth (period 2002-2005)	StockVehicles (x1000)	Growth (period 2005-2010)	StockVehicles (x1000)	Growth (period 2010-2015)	StockVehicles (x1000)	Growth (period 2015-2020)	StockVehicles (x1000)	Growth (period 2002-2005)	StockVehicles (x1000)	Growth (period 2005-2010)	StockVehicles (x1000)	Growth (period 2010-2015)	StockVehicles (x1000)	Growth (period 2015-2020)	StockVehicles (x1000)	StockVehicles (x1000)	StockVehicles (x1000)	StockVehicles (x1000)	StockVehicles (x1000)
BE	0,1%	0,01%	3,1%	2,3%	0,1%	0,1%	7,4%	581	13,7%	660	9,9%	725	9,0%	791	1,6%	4.881	3,7%	5.060	7,8%	5.456	8,6%	5.928	5.462	5.720	6.181	6.718
FR	13,6%	37,2%	17,9%	15,0%	2,7%	2,6%	7,6%	6.355	12,0%	7.118	11,4%	7.928	11,1%	8.810	5,0%	30.716	6,3%	32.663	5,8%	34.549	5,3%	36.372	37.071	39.781	42.477	45.182
DE	0,0%	0,0%	21,4%	20,2%	0,0%	0,0%	10,1%	2.885	14,2%	3.295	12,3%	3.701	11,3%	4.119	3,9%	46.508	10,2%	51.249	9,1%	55.926	8,0%	60.430	49.392	54.544	59.627	64.549
IT	56,3%	26,4%	12,1%	16,0%	10,3%	10,0%	8,9%	4.085	13,8%	4.650	11,8%	5.198	11,1%	5.776	4,2%	35.229	4,5%	36.806	3,7%	38.181	3,1%	39.356	39.314	41.456	43.379	45.131
LU	0,0%	0,0%	0,2%	0,1%	0,0%	0,0%	10,0%	25	32,1%	33	16,2%	38	11,6%	43	5,0%	303	3,1%	312	3,0%	321	4,4%	335	328	345	360	378
NL	0,0%	0,0%	4,2%	3,4%	0,0%	0,0%	12,3%	1.154	17,6%	1.357	14,0%	1.548	13,0%	1.749	5,6%	7.246	9,5%	7.933	10,4%	8.755	9,5%	9.589	8.400	9.290	10.303	11.338
DK	3,0%	0,2%	1,7%	1,0%	9,2%	9,0%	4,0%	405	6,8%	433	7,9%	467	10,0%	514	3,2%	1.963	3,6%	2.034	2,3%	2.082	1,0%	2.103	2.368	2.467	2.548	2.617
IE	0,0%	0,0%	0,2%	0,7%	0,0%	0,0%	20,3%	288	21,8%	350	14,2%	400	10,7%	443	9,6%	1.609	6,9%	1.721	6,7%	1.836	7,0%	1.965	1.897	2.071	2.236	2.408
UK	0,0%	0,0%	6,6%	12,6%	0,0%	0,0%	6,6%	3.248	17,3%	3.811	14,8%	4.374	14,3%	4.999	4,6%	27.790	8,6%	30.166	7,7%	32.493	7,0%	34.767	31.037	33.977	36.867	39.765
EL	0,0%	4,3%	1,3%	2,1%	0,0%	0,0%	14,0%	1.227	18,5%	1.454	15,6%	1.681	15,1%	1.935	0,4%	3.776	-0,7%	3.751	2,7%	3.853	5,0%	4.044	5.003	5.205	5.534	5.978
PT	23,0%	5,9%	2,7%	2,5%	27,5%	26,5%	7,3%	1.963	21,3%	2.381	19,4%	2.842	19,8%	3.405	5,2%	4.125	8,5%	4.474	8,1%	4.835	6,6%	5.156	6.088	6.856	7.677	8.561
ES	0,0%	12,3%	16,6%	8,2%	0,0%	0,0%	8,4%	443	14,5%	508	14,1%	579	13,8%	659	6,4%	19.984	7,6%	21.510	5,6%	22.718	3,4%	23.492	20.427	22.018	23.297	24.151
AT	4,0%	9,4%	3.0%	1,8%	6,4%	6,2%	9,8%	351	15,4%	405	12,8%	457	10,0%	503	2,6%	4.102	4,4%	4.284	7,0%	4.583	7,6%	4.929	4.453	4.689	5.040	5.432
FI	0,0%	0,0%	1,0%	1,0%	0,0%	0,0%	9,2%	349	15,5%	403	9,6%	441	9,5%	483	2,9%	2.264	3,7%	2.348	3,3%	2.425	3,0%	2.499	2.613	2.751	2.866	2.982
SE	0,0%	0,0%	2,8%	1,9%	0,0%	0,0%	12,2%	459	12,8%	518	11,6%	578	9,5%	633	1,7%	4.125	-0,2%	4.118	3,1%	4.244	5,5%	4.478	4.584	4.636	4.822	5.111
EU15	**100%**	**95,7%**	**94,8%**	**88,9%**	**3,3%**	**3,2%**	**8,8%**	**23.817**	**14,4%**	**27.375**	**12,6%**	**30.957**	**12,0%**	**34.861**	**4,4%**	**194.620**	**6,8%**	**208.429**	**6,4%**	**222.256**	**5,8%**	**235.441**	**218.437**	**235.804**	**253.213**	**270.303**
CY	0,0%	0,0%	0,5%	0,2%	0,0%	0,0%	8,1%	127	11,9%	142	10,6%	158	8,2%	170	6,3%	309	9,5%	338	8,7%	368	6,7%	392	436	481	525	563
CZ	0,0%	0,0%	1,0%	1,7%	0,0%	0,0%	-2,1%	342	2,4%	350	2,4%	359	4,6%	375	5,8%	3.883	9,8%	4.264	9,9%	4.687	8,5%	5.087	4.225	4.615	5.046	5.462
EE	0,0%	0,0%	0,2%	0,2%	0,0%	0,0%	37,5%	110	13,8%	126	8,1%	136	5,0%	143	4,9%	426	9,7%	467	9,8%	513	7,1%	549	536	593	649	692
HU	0,0%	2,5%	0,8%	1,3%	0,0%	0,0%	16,3%	465	22,2%	569	18,2%	672	13,3%	761	9,1%	2.781	16,1%	3.228	12,4%	3.629	7,7%	3.907	3.246	3.797	4.301	4.669
LV	0,0%	0,0%		0,3%	0,0%	0,0%	45,0%	149	42,9%	213	26,7%	270	15,8%	312	4,1%	656	12,1%	736	15,5%	850	10,7%	941	805	949	1.119	1.253
LT	0,0%	0,0%	0,8%	0,6%	0,0%	0,0%	26,9%	134	32,1%	177	24,3%	220	18,1%	260	6,9%	1.278	23,6%	1.580	21,6%	1.921	20,6%	2.316	1.412	1.757	2.141	2.576
MT	0,0%	0,0%		0,1%	0,0%	0,0%	6,9%	53	10,3%	59	9,3%	64	8,5%	70	7,0%	220	10,3%	243	9,4%	266	5,7%	281	274	302	330	351
PL	0,0%	0,0%	0,7%	5,7%	0,0%	0,0%	7,3%	2.320	19,2%	2.766	25,8%	3.481	24,7%	4.342	4,3%	11.589	14,7%	13.290	18,2%	15.706	19,0%	18.698	13.909	16.057	19.187	23.040
SK	0,0%	0,0%	0,5%	0,6%	0,0%	0,0%	32,4%	227	33,8%	303	31,1%	398	28,2%	510	7,1%	1.437	15,8%	1.664	17,1%	1.948	14,6%	2.233	1.663	1.967	2.346	2.743
SI	0,0%	1,8%	0,8%	0,4%	0,0%	0,0%	34,7%	81	26,7%	103	18,4%	122	15,6%	141	6,0%	972	6,5%	1.035	2,5%	1.061	1,8%	1.079	1.053	1.138	1.182	1.220
EU25	**100%**	**100,0%**	**100%**	**100%**	**2,9%**	**2,8%**	**9,2%**	**27.826**	**15,0%**	**32.184**	**13,5%**	**36.836**	**12,8%**	**41.946**	**4,5%**	**218.170**	**7,4%**	**235.274**	**7,2%**	**253.204**	**6,6%**	**270.925**	**245.996**	**267.458**	**290.040**	**312.871**

Table 13: *Statistical data (conti.)*

E.3.1 Concept 1 - Common DSRC stack and EFC application

In order to accept this type of OBU, some existing systems would need to upgrade the RSE's. Afterwards, local OBUs and the new (Common DSRC stack and EFC application) OBU can be accepted in the same lane (Multi-RSE concept). In some of the systems, it is simply a minor software adaptation, in order to accept a common European transaction. However, in other systems (like Telepass, it would be necessary a major hardware adaptation).

In order to estimate the financial impact of the Multi-RSE, a simulator was built using Excel worksheets. For each EU member it is possible to indicate whether the Multi-RSE is necessary (TRUE/FALSE). If yes, the table is automatically filled with the current number of lanes and a forecast to 2015, based in the economic growth. The financial impact is then calculated for the following scenarios:

- Percentage of lanes where installation of Multi-RSE is necessary: 20, 30, 50, 80 100;
- Delta cost of the Multi-RSE (in k€): 5.0; 7.5; 10; 12.5; 15.0;
- Development cost: 1 or 2 million Euros.

According to the work of Tasks 1 to 3, currently Telepass is the implementation where the migration has a more relevant impact. Assuming that in 2015 there will be 2500 EFC lanes in Italy (this value is fixed and not calculated based on the current figures and the forecasted growth), the economic impact of introducing Multi-protocol RSEs would be one presented in Table 14.

Year 2015 scenarios													
			QEM (score)	Concept 1: RSE adaptation where required; Development cost = 1M;€; Adaptation cost per lane=					Concept 1: RSE adaptation where required; Development cost = 2M;€; Adaptation cost per lane=				
	%	Nb		5,0k€	7,5k€	10,0k€	12,5k€	15,0k€	5,0k€	7,5k€	10,0k€	12,5k€	15,0k€
Lanes	20%	500	65	4	5	6	7	9	5	6	7	8	10
	30%	750	65	5	7	9	10	12	6	8	10	11	13
	50%	1250	65	7	10	14	17	20	8	11	15	18	21
	80%	2000	65	11	16	21	26	31	12	17	22	27	32
	100%	2500	65	14	20	26	32	39	15	21	27	33	40
				Cost M€									

Table 14: Multi-RSE cost impact in Telepass

In this exercise the financial impact of the Dual DSRC/EFC OBU usage is calculated based in the following assumptions:

- Development cost: 1,5 million Euros per European manufacturer (equals 7,5 million Euros);
- OBU delta price: between 1 and 5 Euros;
- Growth in the total number of equipped vehicles: 10 to 30% per year;
- European OBU adoption rate (%): 5, 10, 20, 30, 50, 80, 100;
- No premature substitution;

- Impact calculation until 2015.

The results are presented in Table 15 (passenger cars), Table 16 (heavy vehicles) and Table 17 (total vehicles).

E.3.2 Concept 2a/b - Dual DSRC/EFC OBU

In this exercise the financial impact of the Dual DSRC/EFC OBU usage is calculated based in the following assumptions:

- Development cost: 1,5 million Euros per European manufacturer (equals 7,5 million Euros);
- OBU delta price: between 1 and 5 Euros;
- Growth in the total number of equipped vehicles: 10 to 30% per year;
- European OBU adoption rate (%): 5, 10, 20, 30, 50, 80, 100;
- No premature substitution;
- Impact calculation until 2015.

The results are presented in Table 15 (passenger cars), Table 16 (heavy vehicles) and Table 17 (total vehicles).

Year 2015 Passenger Cars scenarios (Cost M€)

Total OBUs x10^6	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 5% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 10% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 20% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €
23	9%	46	1	9	10	11	12	13	2	10	12	14	17	19	5	12	17	21	26	30
25	10%	46	1	9	10	11	13	14	3	10	13	15	18	20	5	13	18	23	28	33
28	11%	46	1	9	10	12	13	14	3	10	13	16	19	21	6	13	19	24	30	35
30	12%	46	2	9	11	12	14	15	3	11	14	17	20	23	6	14	20	26	32	38
33	13%	46	2	9	11	12	14	16	3	11	14	17	21	24	7	14	21	27	34	40
35	14%	46	2	9	11	13	15	16	4	11	15	18	22	25	7	15	22	29	36	43
38	15%	46	2	9	11	13	15	17	4	11	15	19	23	26	8	15	23	30	38	45
51	20%	46	3	10	13	15	18	20	5	13	18	23	28	33	10	18	28	38	48	58

Total OBUs x10^6	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 30% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 50% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €
23	9%	46	7	14	21	28	35	42	11	19	30	42	53	64
25	10%	46	8	15	23	30	38	45	13	20	33	45	58	71
28	11%	46	8	16	24	33	41	49	14	21	35	49	63	77
30	12%	46	9	17	26	35	44	53	15	23	38	53	68	83
33	13%	46	10	17	27	37	47	57	16	24	40	57	73	90
35	14%	46	11	18	29	39	50	61	18	25	43	61	78	96
38	15%	46	11	19	30	42	53	64	19	26	45	64	83	102
51	20%	46	15	23	38	53	68	83	25	33	58	83	109	134

Total OBUs x10^6	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 80% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 100% of New DualDSRC/EFC with delta cost = 1 €	2 €	3 €	4 €	5 €
23	9%	46	18	26	44	62	80	99	23	30	53	76	99	121
25	10%	46	20	28	48	68	89	109	25	33	58	83	109	134
28	11%	46	22	30	52	74	97	119	28	35	63	91	119	147
30	12%	46	24	32	56	80	105	129	30	38	68	99	129	159
33	13%	46	26	34	60	86	113	139	33	40	73	106	139	172
35	14%	46	28	36	64	93	121	149	35	43	78	114	149	185
38	15%	46	30	38	68	99	129	159	38	45	83	121	159	197
51	20%	46	41	48	89	129	170	210	51	58	109	159	210	261

Table 15: Dual DSRC/EFC OBU cost impact – Passenger cars

Year 2015 HGV scenarios																																												
Total OBUs x10^6	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 5% of New DualDSRC/EFC with delta cost =					New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 10% of New DualDSRC/EFC with delta cost =					New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 20% of New DualDSRC/EFC with delta cost =					New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 30% of New DualDSRC/EFC with delta cost =					New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 50% of New DualDSRC/EFC with delta cost =					New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 80% of New DualDSRC/EFC with delta cost =					New OBUs (x10^6)	Concept 2b: Development cost = 7.5M€; 100% of New DualDSRC/EFC with delta cost =				
				1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
3	9%	46	0	8	8	8	8	8	0	8	8	8	9	9	1	8	9	9	10	11	1	8	9	10	11	12	2	9	11	12	14	16	3	10	13	15	18	21	3	11	14	17	21	24
4	10%	46	0	8	8	8	8	8	0	8	8	9	9	9	1	8	9	10	10	11	1	9	10	11	12	13	2	9	11	13	15	17	3	10	13	16	19	22	4	11	15	19	22	26
4	11%	46	0	8	8	8	8	9	0	8	8	9	9	10	1	8	9	10	11	12	1	9	10	11	12	14	2	10	12	14	16	18	3	11	14	17	20	24	4	12	16	20	24	28
4	12%	46	0	8	8	8	8	9	0	8	8	9	9	10	1	8	9	10	11	12	1	9	10	11	13	14	2	10	12	14	16	19	4	11	15	18	22	25	4	12	16	21	25	30
5	13%	46	0	8	8	8	8	9	0	8	8	9	9	10	1	8	9	10	11	12	1	9	10	12	13	15	2	10	12	15	17	19	4	11	15	19	23	27	5	12	17	22	27	31
5	14%	46	0	8	8	8	9	9	1	8	9	9	10	10	1	9	10	11	12	13	2	9	11	12	14	15	3	10	13	15	18	20	4	12	16	20	24	28	5	13	18	23	28	33
6	15%	46	0	8	8	8	9	9	1	8	9	9	10	10	1	9	10	11	12	13	2	9	11	12	14	16	3	10	13	16	19	21	4	12	16	21	25	30	6	13	19	24	30	35
7	20%	46	0	8	8	9	9	9	1	8	9	10	10	11	1	9	10	12	13	15	2	10	12	14	16	19	4	11	15	19	22	26	6	13	19	25	31	37	7	15	22	30	37	44
			Cost M€																																									

Table 16: Dual DSRC/EFC OBU cost impact – Heavy vehicles

Year 2015 Total Vehicles scenarios

Total OBUs ($x10^6$)	%Vehicles with OBU	QEM (score)	New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 5% of New DualDSRC/EFC with delta cost =					New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 10% of New DualDSRC/EFC with delta cost =				
				1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	**9%**	**46**	**1**	9	10	11	13	14	**3**	10	13	15	18	21
29	**10%**	**46**	**1**	9	10	12	13	15	**3**	10	13	16	19	22
32	**11%**	**46**	**2**	9	11	12	14	15	**3**	11	14	17	20	23
35	**12%**	**46**	**2**	9	11	13	14	16	**3**	11	14	18	21	25
38	**13%**	**46**	**2**	9	11	13	15	17	**4**	11	15	19	23	26
41	**14%**	**46**	**2**	10	12	14	16	18	**4**	12	16	20	24	28
44	**15%**	**46**	**2**	10	12	14	16	18	**4**	12	16	21	25	29
58	**20%**	**46**	**3**	10	13	16	19	22	**6**	13	19	25	31	37

Total OBUs ($x10^6$)	New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 20% of New DualDSRC/EFC with delta cost =					New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 30% of New DualDSRC/EFC with delta cost =				
		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	**5**	13	18	23	28	34	**8**	15	23	31	39	47
29	**6**	13	19	25	31	37	**9**	16	25	34	42	51
32	**6**	14	20	27	33	39	**10**	17	27	36	46	55
35	**7**	14	21	28	35	42	**10**	18	28	39	49	60
38	**8**	15	23	30	38	45	**11**	19	30	41	53	64
41	**8**	16	24	32	40	48	**12**	20	32	44	56	68
44	**9**	16	25	34	42	51	**13**	21	34	47	60	73
58	**12**	19	31	42	54	66	**17**	25	42	60	77	95

Total OBUs ($x10^6$)	New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 50% of New DualDSRC/EFC with delta cost =					New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 80% of New DualDSRC/EFC with delta cost =					New OBUs ($x10^6$)	Concept 2b: Development cost = 7.5M€; 100% of New DualDSRC/EFC with delta cost =				
		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	**13**	21	34	47	60	73	**21**	28	49	70	91	112	**26**	34	60	86	112	138
29	**15**	22	37	51	66	80	**23**	31	54	77	100	124	**29**	37	66	95	124	153
32	**16**	23	39	55	71	87	**26**	33	59	84	110	135	**32**	39	71	103	135	167
35	**17**	25	42	60	77	95	**28**	35	63	91	119	147	**35**	42	77	112	147	182
38	**19**	26	45	64	83	102	**30**	38	68	98	128	158	**38**	45	83	121	158	196
41	**20**	28	48	68	89	109	**32**	40	72	105	137	170	**41**	48	89	129	170	211
44	**22**	29	51	73	95	116	**35**	42	77	112	147	182	**44**	51	95	138	182	225
58	**29**	37	66	95	124	153	**46**	54	100	147	193	240	**58**	66	124	182	240	298

Cost M€

Table 17: Dual DSRC/EFC OBU cost impact – Total vehicles

E.3.3 Dual DSRC/Common EFC OBU

In this exercise the financial impact of the Dual DSRC/Common EFC OBU usage is calculated based in the following assumptions:

- Development cost: 1,5 million Euros per European manufacturer (equals 7,5 million Euros);
- OBU delta price: between 1 and 5 Euros;
- Growth in the total number of equipped vehicles: 10 to 30% per year;
- European OBU adoption rate (%): 5, 10, 20, 30, 50, 80, 100;
- No premature substitution;
- Impact calculation until 2015.

This type of OBU already has the Telepass DSRC interface but, in order to being used in Italy, it would be necessary to adapt the RSE introducing the common EFC transaction. Therefore, the following additional assumptions are made:

- RSE delta price: 2K €;
- Percentage of lanes where adaptation is necessary: 100, 50, 25.

The results are presented in Table 18 (100% equipped lanes), Table 19 (50% equipped lanes) and Table 20 (25% equipped lanes).

Year 2015 Total Vehicles scenarios – 2500 Lanes – Cost M€

Total OBUs (x10^6)	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 5% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	9%	47	1	14	15	16	18	19
29	10%	47	1	14	15	17	18	20
32	11%	47	2	14	16	17	19	20
35	12%	47	2	14	16	18	19	21
38	13%	47	2	14	16	18	20	22
41	14%	47	2	15	17	19	21	23
44	15%	47	2	15	17	19	21	23
58	20%	47	3	15	18	21	24	27

Total OBUs (x10^6)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 10% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	3	15	18	20	23	26
29	3	15	18	21	24	27
32	3	16	19	22	25	28
35	3	16	19	23	26	30
38	4	16	20	24	28	31
41	4	17	21	25	29	33
44	4	17	21	26	30	34
58	6	18	24	30	36	42

Total OBUs (x10^6)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 20% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	5	18	23	28	33	39
29	6	18	24	30	36	42
32	6	19	25	32	38	44
35	7	19	26	33	40	47
38	8	20	28	35	43	50
41	8	21	29	37	45	53
44	9	21	30	39	47	56
58	12	24	36	47	59	71

Total OBUs (x10^6)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 30% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	8	20	28	36	44	52
29	9	21	30	39	47	56
32	10	22	32	41	51	60
35	10	23	33	44	54	65
38	11	24	35	46	58	69
41	12	25	37	49	61	73
44	13	26	39	52	65	78
58	17	30	47	65	82	100

Total OBUs (x10^6)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 50% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	13	26	39	52	65	78
29	15	27	42	56	71	85
32	16	28	44	60	76	92
35	17	30	47	65	82	100
38	19	31	50	69	88	107
41	20	33	53	73	94	114
44	22	34	56	78	100	121
58	29	42	71	100	129	158

Total OBUs (x10^6)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 80% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	21	33	54	75	96	117
29	23	36	59	82	105	129
32	26	38	64	89	115	140
35	28	40	68	96	124	152
38	30	43	73	103	133	163
41	32	45	77	110	142	175
44	35	47	82	117	152	187
58	46	59	105	152	198	245

Total OBUs (x10^6)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 100% of New DualDSRC/CommonEFC with delta cost = 1 €	2 €	3 €	4 €	5 €
26	26	39	65	91	117	143
29	29	42	71	100	129	158
32	32	44	76	108	140	172
35	35	47	82	117	152	187
38	38	50	88	126	163	201
41	41	53	94	134	175	216
44	44	56	100	143	187	230
58	58	71	129	187	245	303

Table 18: Dual DSRC/Common EFC OBU cost impact – 100% equipped lanes

Year 2015 Total Vehicles scenarios — 1250 Lanes — Cost M€

Total OBUs (x10^6)	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 5% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 10% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 20% of New DualDSRC/CommonEFC with delta cost =				
				1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	**9%**	**47**	**1**	11	13	14	15	17	**3**	13	15	18	20	23	**5**	15	20	26	31	36
29	**10%**	**47**	**1**	11	13	14	16	17	**3**	13	16	19	22	25	**6**	16	22	27	33	39
32	**11%**	**47**	**2**	12	13	15	16	18	**3**	13	16	20	23	26	**6**	16	23	29	36	42
35	**12%**	**47**	**2**	12	13	15	17	19	**3**	13	17	20	24	27	**7**	17	24	31	38	45
38	**13%**	**47**	**2**	12	14	16	18	19	**4**	14	18	21	25	29	**8**	18	25	33	40	48
41	**14%**	**47**	**2**	12	14	16	18	20	**4**	14	18	22	26	30	**8**	18	26	34	42	51
44	**15%**	**47**	**2**	12	14	17	19	21	**4**	14	19	23	27	32	**9**	19	27	36	45	54
58	**20%**	**47**	**3**	13	16	19	22	25	**6**	16	22	27	33	39	**12**	22	33	45	56	68

Total OBUs (x10^6)	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 30% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 50% of New DualDSRC/CommonEFC with delta cost =				
				1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	**9%**	**47**	**8**	18	26	33	41	49	**13**	23	36	49	62	75
29	**10%**	**47**	**9**	19	27	36	45	54	**15**	25	39	54	68	83
32	**11%**	**47**	**10**	20	29	39	48	58	**16**	26	42	58	74	90
35	**12%**	**47**	**10**	20	31	41	52	62	**17**	27	45	62	80	97
38	**13%**	**47**	**11**	21	33	44	55	67	**19**	29	48	67	85	104
41	**14%**	**47**	**12**	22	34	47	59	71	**20**	30	51	71	91	112
44	**15%**	**47**	**13**	23	36	49	62	75	**22**	32	54	75	97	119
58	**20%**	**47**	**17**	27	45	62	80	97	**29**	39	68	97	126	155

Total OBUs (x10^6)	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 80% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 100% of New DualDSRC/CommonEFC with delta cost =				
				1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	**9%**	**47**	**21**	31	52	73	94	114	**26**	36	62	88	114	141
29	**10%**	**47**	**23**	33	56	80	103	126	**29**	39	68	97	126	155
32	**11%**	**47**	**26**	36	61	87	112	138	**32**	42	74	106	138	170
35	**12%**	**47**	**28**	38	66	94	121	149	**35**	45	80	114	149	184
38	**13%**	**47**	**30**	40	70	100	131	161	**38**	48	85	123	161	199
41	**14%**	**47**	**32**	42	75	107	140	172	**41**	51	91	132	172	213
44	**15%**	**47**	**35**	45	80	114	149	184	**44**	54	97	141	184	228
58	**20%**	**47**	**46**	56	103	149	196	242	**58**	68	126	184	242	300

Table 19: Dual DSRC/Common EFC OBU cost impact – 50% equipped lanes

Year 2015 Total Vehicles scenarios — 625 Lanes

Total OBUs (x10^6)	%Vehicles with OBU	QEM (score)	New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 5% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 10% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 20% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 30% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 50% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 80% of New DualDSRC/CommonEFC with delta cost =					New OBUs (x10^6)	Concept 2a: Development cost = 7.5M€; Adaptation cost per lane = 2k€; 100% of New DualDSRC/CommonEFC with delta cost =				
x10^6				1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €		1 €	2 €	3 €	4 €	5 €
26	9%	47	1	10	11	13	14	15	3	11	14	17	19	22	5	14	19	24	30	35	8	17	24	32	40	48	13	22	35	48	61	74	21	30	51	71	92	113	26	35	61	87	113	139
29	10%	47	1	10	12	13	15	16	3	12	15	17	20	23	6	15	20	26	32	38	9	17	26	35	44	52	15	23	38	52	67	81	23	32	55	78	102	125	29	38	67	96	125	154
32	11%	47	2	10	12	14	15	17	3	12	15	18	22	25	6	15	22	28	34	41	10	18	28	37	47	57	16	25	41	57	73	89	26	34	60	85	111	136	32	41	73	104	136	168
35	12%	47	2	10	12	14	16	17	3	12	16	19	23	26	7	16	23	30	37	44	10	19	30	40	51	61	17	26	44	61	78	96	28	37	64	92	120	148	35	44	78	113	148	183
38	13%	47	2	11	13	14	16	18	4	13	16	20	24	28	8	16	24	31	39	46	11	20	31	43	54	65	19	28	46	65	84	103	30	39	69	99	129	160	38	46	84	122	160	197
41	14%	47	2	11	13	15	17	19	4	13	17	21	25	29	8	17	25	33	41	49	12	21	33	45	57	70	20	29	49	70	90	110	32	41	74	106	139	171	41	49	90	131	171	212
44	15%	47	2	11	13	15	17	20	4	13	17	22	26	31	9	17	26	35	44	52	13	22	35	48	61	74	22	31	52	74	96	118	35	44	78	113	148	183	44	52	96	139	183	226
58	20%	47	3	12	15	17	20	23	6	15	20	26	32	38	12	20	32	44	55	67	17	26	44	61	78	96	29	38	67	96	125	154	46	55	102	148	194	241	58	67	125	183	241	299

Cost M€

Table 20: Dual DSRC/Common EFC OBU cost impact – 25% equipped lanes

E.4 Cost evaluation

A cost-benefit analysis was made for the following technical scenarios:

- Concept 1 - Common DSRC stack and EFC application
- Concept 2a – Dual DSRC stacks and common EFC application
- Concept 2b - Dual DSRC stacks and dual EFC applications

For each one of these scenarios it was considered the result of the qualitative analyses (69, 47 and 41, respectively) and the medium term financial impact:

- Concept 1 - Common DSRC stack and EFC application: 1M€ development cost and lane delta cost 10k€

- Concept 2a – Dual DSRC stacks and common EFC application: 100% equipped lanes, 50% penetration rate, 5M€ development cost, 2k€ adaptation cost per lane and delta cost 3€
- Concept 2b - Dual DSRC stacks and dual EFC applications: total vehicles, 50% penetration rate, 7,5M€ development cost and delta cost 3€

Results are described in Section 6.3.

ANNEX F– INTEROPERABILITY – FRANCE AND NORWAY

This annex is quotes a public document sent by the NPRA to ASFA to follow up the tests carried out by ASFA and Q-Free and to confirm what had been presented by the ASFA to the Télépéage Committee of June 20, 2003.

INTEROPERABILITY BETWEEN TIS (FRANCE) AND AUTOPASS (NORWAY)

INTRODUCTION

The French national electronic toll collection (ETC) system – TIS - and its Norwegian counterpart are two of Europe's largest operational implementations with 1.4 million and 1.2 million subscribers respectively. Both systems use the tried and tested microwave technology Dedicated Short Range Communication (DSRC) at 5.8 GHz, which has been successfully harmonised in Europe by CEN (Comité Européen de Normalisation). Despite some differences in the specifications used in the two systems they are in essence the same, thus technical interoperability between equipment of the respective systems is already there. This means that readers from one system can also read OBUs from the other system.

TIS and AutoPASS and the European Standards

Both systems are compliant with the CEN DSRC European standards and the EFC application standard ISO 14906.

CEN DSRC – at the level of Layer 2 and 7 of the CEN DSRC standards the TIS system and AutoPASS are similar in effect. The physical layer (Layer 1) implemented by TIS and AutoPASS is differing only in some parameters but both are within the CEN DSRC standards. Based on these facts interoperability is achievable in tolling. Initial tests both within the TIS system and the AutoPASS system have been performed and confirm this. The AutoPASS OBU meets the levels set by the TIS specification, and the TIS OBUs will work in the AutoPASS motorway plazas.

ISO 14906: EFC Application of CEN DSRC – both systems use the same application sequence. This makes the two applications easy to implement in parallel in the same reader.

- Initialisation: This phase uses BST/VST in exactly the same manner
- Read information from OBU: This phase reads the same information, using slightly different commands GET and GET_SECURE
- Write information to OBU: This phase writes the same info using the same command – SET
- End transaction: The communication is stopped by the RELEASE command

The Position Today

The technical interoperability between the French TIS system and AutoPASS from Norway is based on realities. Extensive laboratory tests have already been conducted in both France and Norway to show that a TIS OBU is interoperable with an AutoPASS reader, and vice versa. Further tests are planned to be conducted on live installations.

ANNEX G– CEN EFC NEW WORK ITEMS

This annex is an excerpt from CEN documents[13] that define the scope of the recently adopted new EFC works items that will define the

- Minimum Interoperable Specification for DSRC-EFC transactions
- Conformity evaluation of OBU and RSE to "DSRC-MIS EFC application transaction requirements"

G.1 DSRC-EFC transaction specification

Scope

The scope for the standard is limited to:

- Payment method: Central account based on EFC-DSRC.
- Physical systems: OBU, RSE and the interface between them (all functions and information flows related to these physical parts).
- DSRC-link requirements (see above).
- EFC transaction (for the interface as above).
- Data elements to be used by OBU and RSE.
- Security mechanisms for OBU and RSE.

It is outside the scope of this NWI to define:

- Contractual and procedural interoperability requirements (including MoU issues).
- Conformance procedures and test specification ().
- Setting-up of central organisations (e.g. clearing operator, trusted third party, conformance test house) etc.
- Legal issues.
- Other payment methods (e.g. on-board accounts using smart cards).
- Other basic technologies (e.g. GNSS/CN or video registration).
- Other interfaces or functions in EFC-systems than those specified above.

Please note that some of these issues are subject to additional separate NWI proposals currently being prepared by CEN/TC278/WG1.

Justification

Interoperability between DSRC-based EFC systems in Europe is one to the most important objectives for standardisation work in the field of EFC. The need for an interoperable European toll service based on EFC standards is called for by the adopted Directive (2004/52/EC) on interoperability of electronic road toll systems, and the mandate m/338 on how standardisation might support these efforts.
Recently "Proposed standardization work and recommendations in response to EFC directive (2004/52/EC) and the related mandate M/338" (CEN / TC278 N1663) also calls for the development of a Minimum Interoperable Specification (MIS) for European DSRC-EFC transactions.
The needs and benefits of interoperable DSRC-EFC are well established in several previous projects and reports.

CEN/TC278 (/WG1) has produced several standards that support interoperable DSRC-EFC-systems, in particular EN ISO 14906, a "toolbox" for EFC transactions. However, these standards are of enabling nature and do no guarantee interoperability. Further specifications are needed for technical interoperability to be achieved.

[13] [CEN EFC]

The elaboration of the concept in the new standard will be based on the results of the European projects CARDME, PISTA and CESARE, as they represent the fruit of European EFC harmonisation and have been used as the basis for several national implementations.
The NWI will be based on

- EN ISO 14906 (“DSRC EFC application interface definition”)
- CEN prEN / ISO DIS 14816 (“Numbering and data structures”)
- EN 12834 (“DSRC Application layer”)

The DSRC communication protocol will be defined, e.g. by reference to the relevant DSRC profiles defined in EN 13372 (“DSRC Profiles”).

The objective is to define a standard that defines a “Minimum Interoperable Specification for DSRC-EFC transactions”. The standard contains parts on:

- DSRC requirements (i.e. how to use existing DSRC-standards for unambiguous technical interoperability).
- EFC transaction requirements
- Security features
- Data requirements (including classification data)

This proposal is for the development of a common technical platform (protocol) in form of a Minimum Interoperable Specification (MIS) for European DSRC-EFC transactions that European EFC-systems may migrate towards. The standard sets a common and basic level of technical interoperability fully enabling procedural and contractual interoperability elements to be added.

Each operator (of an RSE) or issuer (of OBE) adheres to the standard by implementing the standard in the design of RSE and OBE. Ideally the standard can be used as a technical platform in a MoU (or MoU organisation) designed to cater for interoperability between operators (and issuers).

The standard is designed to allow for additional local solutions (e.g. local transactions, data elements, security provisions, etc.). This allows for co-existence of local system and graceful migration from existing legacy EFC-systems to interoperable pan-European EFC-systems.

As the standard defines one single common protocol for interoperable use, no local implementation should need to implement more than two protocols in OBEs and RSEs (one local and one interoperable), as the interoperable protocol may cater for all “foreign” transactions.

The standard will not define any date or schedule for phasing out existing systems.

G.2 Conformity evaluation of OBU and RSE

Scope

The scope of this “test specification” corresponds to the scope of the requirements specification, i.e. “DSRC MIS EFC application transaction requirements” focusing on the critical interoperability elements from a technical interoperability perspective:

- Payment method: Central account based on EFC-DSRC;
- Physical systems: OBU, RSE and the interface between them (all functions and information flows related to these physical parts);
- DSRC-link (for the interface as above);
- EFC transaction (for the interface as above);
- Data elements to be used by OBU and RSE;
- Security mechanisms for OBU and RSE;
- Conformance procedures and test specification.

It is outside the scope of this NWI to define tests that assess:

- performance;
- robustness;
- reliability of an implementation.

Note that the OBU and RSE will be subject to additional testing in order to ascertain that they fulfil the essential requirements as set out in European Directives – a pre-requisite for CE marking and placing on the European market. They are also likely to be subject to additional testing of physical, environmental endurance, quality assurance and control at manufacturing, charge point integration, as part of factory, site and system acceptance testing. The definition of these tests is outside the scope of this NWI.

Justification

Interoperability between DSRC-based EFC systems in Europe is one to the most important objectives for standardisation work in the field of EFC. The need for an interoperable European toll service based on EFC standards is called for by the adopted Directive (2004/52/EC) on the interoperability of electronic road toll systems, and the mandate m/338 on how standardisation might support these efforts.
Recently “Proposed standardization work and recommendations in response to EFC directive (2004/52/EC) and the related mandate M/338” (CEN / TC278 N1663) also calls for the development of a Minimum Interoperable Specification (MIS) for European DSRC-EFC transactions and the associated “conformance evaluation test specification” (i.e. this proposed new work item).
The needs and benefits of interoperable DSRC-EFC are well established in several previous projects and reports. A standard on conformity evaluation is a necessary element for coherent, practical and effective of appraisal of products’ compliance to the MIS requirements.

CEN/TC278(/WG1) has produced several standards that support interoperable DSRC-EFC-systems, in particular EN ISO 14906 and CEN ISO DTS 14907-2, a “toolbox” for EFC transactions and conformance testing. However, these standards are of enabling nature and do no guarantee interoperability. Further specifications are needed for technical interoperability to be achieved.

This proposed new work item on Conformity evaluation of OBU and RSE to “DSRC-MIS EFC application transaction requirements” will be based on:

- “DSRC-MIS EFC application transaction requirements”
- CEN ISO DTS 14907-2 on “OBU conformance tests”
- ISO 9646 family of standards on “Tree and tabular combined notation”

The latter is a standardized “language” suitable for specification of test cases and steps for assessment of protocol and application behaviour. The “TTCN language” is also supported by modern automated tools that accelerate software design, implementation and testing.

The objective of this NWI is to develop a standard that defines tests for conformity evaluation of OBU and RSE to “DSRC MIS EFC application transaction requirements”:

- Assess OBU and RSE capabilities;
- Assess OBU and RSE behaviour;
- Serve as a guide for OBU and RSE conformance evaluation and type approval;
- Achieve comparability between the results of the corresponding tests applied in different places at different times;
- Facilitate communications between parties

The standard is intended to be used in the conformity evaluation of OBU and RSE to the “MIS DSRC-EFC application transaction requirements” – proposed in response to the EFC Directive for a European toll service”.

ANNEX H– OVERVIEW OF EUROPEAN EFC SYSTEMS

LEGEND

IF=Infrastructure funding
IEC=Internalisation of external costs
CC=Congestion charging
T=Tax

AR=All roads
PRN=Primary road network
SRN=Secondary road network
MN=Motorway network
M=Motorway
SM=Semi-Motorway
AT=Area tolling
BL=Bridge Link
TR=Toll Ring
B=Bridge
T=Tunnel

EFC scope

Country	Objective	Operator/ operational since	Tolling area	Size of tolling area	Future plans
Austria	IF	EUROPPASS-Autostrade	MN	Km 2.112	−Interoperability with CH achieved −MEDIA project −With D intended
Croatia	IF IF IF	Autocesta Rijeka-Zagreb (ARZ) BINA-ISTRA Hrvatske Autoceste (HAC)	SM M/SM M/T	Km 731	No information
Czech	**				Plans for EFC introduction
Denmark	IF IF	A/S Storebælt Øresundsbro Konsortiet	BL BL	Km 34	−NORTIS project
Estonia	**				No information
Finland	**	No toll roads		Km 602	−NORTIS project
France	IF	ASFA 11 Motorway Operators	M/B/T	Km 7895	–Extension to HGV –Interoperability with ES –MEDIA project
Germany	IF IF IF	TOLL COLLECT GmbH (01-01-2005) Warnowquerung GmbH & Co. KG Herrentunnel GmbH & Co. KG (01-09-05)	MN HGV T T	Km 12.350 Km 1 Km 2.1	- Interoperability with neighboring countries
Great Britain	IF CG	M6 Central London Congestion Charging Mersey Tunnel, DRC, Severn Bridge	M AT	Km 50 Km2 21	- Bid for tender on all roads in 2005 - HMCE's LRUC

EFC scope

Country	Objective	Operator/ operational since	Tolling area	Size of tolling area	Future plans
Greece	IF	ATTIKI-Odos/EGNATIA-Odos TEO	M (north of Athens) M	Km 750 Km 916	Planned motorway length extension to 2100 Km
Hungary	IF	No EFC operator	M	Km 539	
Ireland	**		M	Km 40	
Italy	IF	AISCAT 24 Motorway Operators	M	Km 5593	−Interoperability with AT −MEDIA project
Lithuania	**				No information
Nederland	n.a.	n.a.			
Norway	IF	NORVEGFINANS 33 Motorway Operators	M/TR/B/T	Km 649	–NORTIS project –Svinesund bridge
Poland	**				No information

EFC scope

Country	Objective	Operator/ operational since	Tolling area	Size of tolling area	Future plans
Portugal	IF	AENOR (1999) ATLANTICO (1998) BRISA-VIA VERDE(1995) LUSOPONTE (1995)	M M M B	Km 44 Km 170 Km 1005 Km 23	-75% penetration rate (2006) - Commercial interoperability trial with Spain (Sep/2005)
Slovenia	IF	DARS (07-12-03)	M	Km 316	−Upgrade to CEN DSRC + CARDME −MEDIA project
Spain	IF	ASETA 30 Motorway Operators Under construction (5 EFC domains)	MN/T	Km 2612 Km 586,80	- 90% of the network equipped with EFC lanes -Commercial interoperability trial with Portugal (Sep/2005) -Interoperability with FR
Sweden	IF	Øresundsbro Konsortiet	BL	Km 8	−NORTIS project −Svinesund bridge −Stockholm RUC − HGV
Switzerland	IEC	Swiss Customs Authority, OZD / - 2004	AR	> Km 70.000	–CARDME DRSC interface for the next generation Swiss OBU, 2007; –Interoperability with AT –MEDIA project
Turkey		Izmir – Cesme Highway Turkish Highways, Bosphorus Bridge			

LEGEND

AV=All Vehicles
PC=Passengers Cars
LCV=Light Commercial Vehicles (3.5<t<12)
HGV=Heavy Goods Vehicles
O=Other

E=Emission
NA=Number of axles
HFA=Height first axle
W=Weight
MLW=Maximum Laden Weight
L=Length
T=Trailer
TW=Twin wheels
O=Other

CA=Central Account
PoCA=Central account
PrCA=Central account
OBA=On board account

Tolling criteria

Country	Type of vehicle	Class (Decl/Meas)	Payment means	EFC protocol
Austria	AV ≥ 3.5 t	•NA (2,3,4, 4+) stored in OBU •Consistency check of decl	CA + OBA	•EN 14906 – CARDME •Compatibility to CESARE II and PISTA tested
Croatia				PISTA compliant
Czech				
Denmark	AV	L	CA	
Estonia				
Finland				
France	PC, LGV	L + W: 3 classes Decl	CA	CEN DSRC, CESARE/ PISTA compliant
Germany	HGV ≥ 12t AV AV	NA (2 cl.) + E (3 cat.) Decl NA + HFA NA + HFA	PoPrCA CA CA	OBE <-> CE: GSM protocol EN 14906 – CESARE II EN 14906 – CESARE II
Great Britain (M6)	AV	NA + HFA: 6 classes	PrCA	EN 14906 / OMISS-V3 based on the CARDME / P IST transaction

Tolling criteria

Country	Type of vehicle	Class (Decl/Meas)	Payment means	EFC protocol
Greece		Decl		EN 14906
Hungary				
Ireland				
Italy	AV	NA + HFA (A, B, 3, 4, 5)	PoCA + PrCA	UNI 10607 A-deviation from CEN
Latvia				
Lithuania				
Nederland				
Norway	AV	W (2 cat.) + L (3 cat.): 3 classes	CA	EN 14906 + AutoPASS
Poland				

Tolling criteria

Country	Type of vehicle	Class (Decl/Meas)	Payment means	EFC protocol
Portugal	AV	NA + HFA: 5 cl. Decl.	CA	Low data rate upgraded to CEN DSRC
Slovenia	AV	NA + HFA - Dec	PoCA + PrCA	CARDME
Spain	AV	NA + TW - Dec	CA	14906 + PISTA
Sweden	AV		CA	SwePac including conformity test spec: CARDME / PISTA
Switzerland	HGV>3.5 t	MLW + E Decl.	CA	GPS, Tachograph, CEN DSRC
Turkey				EN 14906

	DSRC link		
Country	**Standard/Other**	**Profile (0, 1, Other)**	**Parameter set (L1-A, L1-B, Other)**
Austria	CEN DSRC	P0, P1	L1-B
Croatia	CEN DSRC		
Czech			
Denmark	CEN DSRC	P0, P1	L1-B
Estonia			
Finland			
France	CEN DSRC		
Germany	DSRC CEN DSRC and infrared CEN DSRC CEN DSRC	P0, P1 (CEN DSRC) P0, P1 P0, P1	L1-B (CEN DSRC) L1-B L1-B
UK	CEN DSRC	P0, P1	L1-B

	DSRC link		
Country	**Standard/Other**	**Profile (0, 1, Other)**	**Parameter set (L1-A, L1-B, Other)**
Greece	CEN DSRC		
Hungary			
Ireland	CEN DSRC		
Italy	UNI 10607 ETSI ES 200 674		
Latvia			
Lithuania			
Nederland			
Norway	CEN DSRC	P0, P1	L1-A
Poland			

	DSRC link		
Country	**Standard/Other**	**Profile (0, 1, Other)**	**Parameter set (L1-A, L1-B, Other)**
Portugal	Migration to CEN DSRC		
Slovenia	2.45 GHz migration to CEN 5.8 GHz		
Spain	CEN DSRC	P1	CESARE II / PISTA
Sweden	CEN DSRC	P0, P1	L1-B
Swiss	CEN DSRC	P0	L1-B
Turkey	CEN DSRC		

	OBE characteristics				
Country	**MMI**	**Power supply**	**VDI**	**OBU issued**	**Formula Sell/Rent**
Austria	•Switch for category change •Led •Buzzer	battery	--	450.000	S
Croatia				15.000	
Czech					
Denmark				125.000	S
Estonia					
Finland					
France	Buzzer	Battery	-	1.400.000	R
Germany	LCD/Keys/Buzzer/LED Buzzer Buzzer	Ext power Battery Battery	Tacho, Gyro,GNSS,GSM - -	380.000 increasing 3.500 16.000/55.000	No costs No costs Open
Great Britain	Buzzer	Battery	-	250.000	S

OBE characteristics					
Country	**MMI**	**Power supply**	**VDI**	**OBU issued**	**Formula Sell/Rent**
Greece				185.000	
Hungary					
Ireland				121.000	
Italy	Buzzer, LED	Battery	--	4.500.000	R
Latvia					
Lithuania					
Nederland					
Norway	-	Battery	-	1.200.000	R
Poland					

OBE characteristics					
Country	**MMI**	**Power supply**	**VDI**	**OBU issued**	**Formula Sell/Rent**
Portugal	--	battery	--	1.750.000	S/R
Slovenia	buzzer	battery	--	250.000	S
Spain	buzzer	battery	--	500.000	S
Sweden				127'000	
Swiss	Display/Keys/Chip card/Buzzer	Ext. power	Tachygraph, trailer sensor	55.000	S
Turkey				535.000	

RSE characteristics

Country	Number of toll stations	Single/Multilane	Enforcement (Det., Class., Reg.)
Austria	800 (2400 lanes)	M	100 gantries laser scanners, video
Croatia	64		
Czech			
Denmark	6	S	DCR
Estonia			
Finland			
France	2.500	S	Barrier
Germany	5.200 sections GPS based + 180 IR beacons 9 1 main station + 1 ramp station	M S S	300 gantries auto DCR DCR DCR
Great Britain	88	S/M	Barrier(DCR

RSE characteristics

Country	Number of toll stations	Single/Multilane	Enforcement (Det., Class., Reg.)
Greece	67	S	
Hungary			
Ireland	18	S	
Italy	456 (2.000 lanes)	S	Barriers, Video
Latvia			
Lithuania			
Nederland			
Norway	100 (328 lanes)	S	Video
Poland			

RSE characteristics			
Country	**Number of toll stations**	**Single/Multilane**	**Enforcement (Det., Class., Reg.)**
Portugal	122 (450 lanes)	S	Video
Slovenia	24 (89 lanes)	S	Barriers + Video
Spain	>900 lanes	S	Barriers
Sweden	7 lanes	S	
Swiss	230		21 control stations (DTR) + 1 mobile control unit
Turkey	128	S	

ANNEX I – REFLECTIONS ON OBU CLASSES

In order to provide full interoperability with all existing European EFC systems without modifications to the DSRC RSE, new types of OBU should support the DSRC 5.8 GHz technologies and associated EFC applications by:

- offering the features needed to support all European EFC services (i.e. a superset of all requirements), Provision of connections to GPS, GSM/GPRS, (chip-)card reader, tachograph, vehicle sensors, HMI CEN DSRC 5,8 GHz, etc. or
- offering a minimum set of features to support all European EFC Services in “degraded mode” (purely DSRC), i.e. a display and keyboard to declare distance, instead of automatic distance recording, etc.

Alternatively it could be viable to define a set of OBU classes. Each class would be associated with a defined set of features. These classes could for example, and illustration purposes, be the following ones:

- OBUs for DSRC systems only (e.g. without distance based recording)
- OBUs for DSRC systems and for distance based charging systems with a limited set features for distance declaration (i.e. "manual" distance declaration)
- OBUs for DSRC systems and GPS/GSM systems for all EFC applications with all features necessary for automatic distance recording/declaration

ANNEX J – REFLECTIONS ON OBU COSTS

Whereas different EFC professionals (industrials, operators, issuers,…) have different views on OBU price projections, the following views on monolithic OBUs are generally shared:

- Free market dynamics and associated pricing require at least three to four independent vendors present.
- An inexpensive monolithic OBU is based on high-volume design (i.e. application specific integrated circuits) and manufacturing process.
- The minimum volume for a vendor to design a new monolithic OBU product and adapt the production is typically around 300k-500k units for "in-house technology". The minimum volume for a product that is based on new technology for the OBU vendor is higher, around 1m - 2 m units. (The Telepass technology is a "new" technology for most of the OBU vendors.)
- The current OBU production capacity of leading vendors is more than 2 million units per year, and is increasing. The current typical high-volume production line capacity is 400k – 1m units per year.
- The two biggest elements that influence the monolithic OBU production cost is the volume and the complexity of the HMI features. The cost is reduced with increased volume.
- The monolithic OBU price is typically increased with 50% on the total OBU production cost (i.e. also referred to as landed unit cost), but varies significantly according to the OBU vendor's market strategy, the regional competition and any existing local pricing precedents. Thus, the margin per unit for a monolithic OBU is relatively small but the volume is relatively large.
- Typical production costs for 500k units vary from €10 to €15 per unit for a monolithic OBU. For the same volume this could increase by 50 to 100% for an OBU with multi-line display, simple keypad and tamper detection capability. For order commitments of 800k to 1m units the landed unit cost could typically decrease by 20-25% although at this high volume the vendor strategy or procurement requirements could include host country manufacturing and custom designs to ensure a further cost reduction. However, any such advantages for marginal volumes would be offset by production start-up costs and initially low yield. An external comparison of potential cost advantage of OBU vendors become more complex at high volumes since this will depend on whether the OBU design inherently assumes a specific manufacturing process (thus limiting choice of contract manufacturers), the vendor’s experience in ‘exporting’ its designs, the changing proportions of currency risk between upstream/component suppliers and perception (realistic or otherwise) of potential long-term volumes in the target market.