AFC Requirements for a Dedicated Short Range Communication
Final Issue: May 1994

Developed and Issued by: CEN TC278 / WG1 / SG2
Document TC278 / WG1 / SG2 / 50.2

Final Issue

AFC Requirements for a DSRC

May 1994

This document is a revision of the first draft input of requirements for a DSRC link to support Automatic Fee Collection issued in October 1994. This document retains most of the text and all of the principles of the original draft plus the support leter in respect of simple and complex systems, and provides additional clarification and, hopefully, more clear explanation.

It is submitted by CEN TC 278 / WG 1 /SG 2 for the attention of WG9 and CEN TC278/PT03, and to assist them in their work.

R Williams
Convenor CEN TC278 WG1 SG2
May 1994

AFC Requirements for a Dedicated Short Range Communication
Final Issue: May 1994

Developed and Issued by: CEN TC278 / WG1 / SG2
Document TC278 / WG1 / SG2 / 50.2

Preface to WG9

This document is the work of the Sub Committee of WG1 (SG2) which was specifically established to determine the AFC requirements for a DSRC.

The committee has met over a considerable period of time, and this output, represents its consolidated requirement. The aspects in this document do not comprise a full set of requirements for AFC, solely those requirements that are likely to affect the DSRC link.

Aware of the time scale pressures on WG9 to determine a link specification, a draft was passed to WG9 in October 1993, and this final version replaces that draft.

With the exception of Table 10 (OBE Transaction cycles per year) there have been no significant changes in the requirements. The presentation and numbering have been ammended for clarity.

In the opinion of SG2 of WG1, this document contains the key requirements for supporting an AFC System as they might relate to the DSRC. The document has been revisedas a result of further consultations, and the communication to WG9 of November 1993 which clarifies the position of WG1 regarding the definition of simple and more complex devices is now included.

For any points where immediate clarification is required, SG2 invites you to consult K.Evensen, who is the liaison link person between WG's 1 & 9, and is a member of both WG's and a member of the SG that has prepared this document

Bob Williams
Convenor

AFC Requirements for a Dedicated Short Range Communication
Final Issue: May 1994

Developed and Issued by: CEN TC278 / WG1 / SG2
Document TC278 / WG1 / SG2 / 50.2

1. INTRODUCTION

The objective of this document is to determine the AFC requirements for a DSRC.
Section 2 details the key issues of philosophy that guide the work of WG1 SG2. This philosophy is consistent with the work of WG13 (Architecture) and with WG12 (AVI/AEI).

The main objectives of an Automatic Fee Collection System are the following:

1. Automatic and efficient collection of charges.
2. Improve/maintain traffic flow
3. Minimisation of collection costs.
4. Improved Services for users
5. Fee Collection in 'all' circumstances

The subsequent sections detail particular aspects of the requirements

2. GUIDING PRINCIPLES AND PHILOSOPHY

2.1 FLEXIBILITY OF STANDARDS

WG1 recognises that TC278 is developing its Standards at a time of rapid development and change. Whilst the most important aspect of the Standards is to provide compatibility/ interchangeability / interoperability within the sector, part of the objectives are also to provide guiding principles for future generations of technology.

In developing the AFC requirements for the DSRC, the WG takes into account the belief that, whatever the solution seems to be now, with the pace of change, a 'final' common solution may not yet be known or developed. Not only technical achievability, but also the economics of the market place and politics will play an important part in the choice or choices made in the sector. Indeed, there is no evidence as yet to support the belief that there will be 'only one single Pan-European System', and Member States and operators may require different solutions of different complexity, particularly in the short and medium term.

From the users point of view, he requires functionality wherever he uses his vehicle. Because of the different levels of complexity of different solutions, that functionality may be at a lower level than is achievable within his home territory, but should be adequate to achieve the minimum requirements of the Standard. This implies 'upwards interoperability' where the more simple devices can be understood by the more complex, and the more complex can make themselves understood by simple systems.

The Standards therefore have to provide as much flexibility as possible, in order to enable the market place to make its choices.

The laudable desire for 'full compatibility', with its benefits of scale and consistency, cannot yet be standardised, and Standards therefore need to provide flexibility of approach. This means that the currently achievable level of Standardisation may only provide interoperability or compatibility to a limited extent.

It is therefore of vital importance that the Standards support both simple devices and highly capable devices and exclude neither option. The choice being for the market place and not the Standardisation body.

However, the objective of Standardisation is to bring order into the market place, and to minimise the chances of incompatibility, and to bring direction to subsequent generations of equipments.

It must therefore be the objective that Standards are ***enabling*** rather than prescriptive, and this must underlie all proposals for RTTT Standardisation (whether EN or ENV) at this stage of development.

The scope of this document is limited to DSRC for the road environment only. Issues of multi-modality are not considered in this document.

2.2 Compatibility/ Interoperability

Let us clearly define what we mean in this respect. WG13 has provided a clear definition, based on the widely accepted NATO definition

The Agreed definitions for use in TC278, and recommended to others is as follows:

COMPATIBILITY

Capability of two or more items or components of equipment or materiel to exist and/or function in the same system or environment without modification, adaption or mutual interference.

INTERCHANGEABILITY

A condition which exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for the other without alteration of the items themselves, or of adjoining items, and without selection for fit and performance.

INTEROPERABILITY

The ability of systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together.

Within this document the interpretation is limited to the AFC functionality, and does not include financial or administrative aspects, nor does it include related or connected devices.

Whilst system compatibility is clearly desirable, **limited interoperability is essential** within an AFC environment where a multi-national or pan European aspect is intended. This implies and requires a capacity for upwards migration.

2.3 Upwards Migration/ Upgrading

If the sector has to support both simple and more capable devices in an interoperable environment, it is essential that the devices are capable of 'upwards migration', either to accommodate both types of device in the emerging specifications, or as new generations of systems are developed.

In the short term (i.e. within the currency of current generations of installed equipment), it may be necessary to require only limited interoperability. i.e. only the non contentious aspects of a system are capable of Standardisation. This is the approach taken by WG12 in its two AVI Draft Standards, where it is only appropriate to standardise the Reference Architecture and Numbering Schemes. Such Standardisation, however limited, does provide a consistent platform for future generations of equipments.

For interoperable (even if not fully compatible) AFC Systems in Europe, it is essential that there is interoperability in respect of the DSRC. i.e., that there is at least limited functionality in the ability for all 'Standard' interrogators to read ***all*** passing vehicle OBE's that comply to the Standard.

Accepting that the market place will require systems of different complexity and capability, *by definition, it is not technically possible to expect a simple system to meet the requirements of a more complex system, without becoming a complex system itself, and defeating the objective philosophy.*

This means that the more capable systems must be able to obtain the available information from the more simple devices, and that the OBE's of more capable systems will be able to provide the limited information to simple systems in a manner that can be understood, whilst the simple systems will continue to be able to be supported in their limited functionality by either system. This imposes constraints on the functionality, and particularly the handshaking, protocols and WG9 are required to take this into account in their system definition.

WG1 has to accommodate both requirements for interurban travel and local urban needs for fee collection. The requirements are different, but the link should support either.

Inter-urban requirements will most probably require a capable solution, particularly on the Pan-European level. Urban requirements for local fee collection, (often of very small fees), are required at low cost without sophistication. Different levels of complexity are also to be expected from different operators in Europe.

Whereas the systems may be different, and the OBE may be different, the one DSRC link protocol should recognise both, without imposing an unnecessary cost burden on the more simple link.

Within WG1 consensus has been obtained to the following:

At the most basic level, a **simple DSRC link** is one where the OBE

* has limited functionality
* operates in read only mode only
* requires little or no processing power for link control
* may be entirely pre-programmed
* operates as a complete slave of the interrogator, not capable of taking the 'initiative' in a transaction

Implicitly such systems provide an early and low cost option in line with the resolutions of TC278. This represents the 'lowest' level of device that may be encountered.

A more **capable DSRC link** is, for example, one

* of higher functional capability both in OBE and interrogator
* where security may be part of the application transaction
* where the OBE may carry additional data capability
* has read /write and/or transactional capability
* may act as a link for other connected devices.

It is the requirement of WG1 that 'simple DSRC Links' must also be accommodated by the link specified for WG1 by WG9. It is for the market place to decide, not the Standardisation body, which solutions will be adopted.

There are some further implications that are important to state.

a) That by supporting a simple level of operation, upwards migration must be possible.

b) There should be a link at the CEPT recommended frequency (5.8 GHz).

c) A read only OBE should be capable of being read by a read/write beacon

d) A 'read/write' OBE should be read in read only mode by a 'read only' beacon.

2.4 Multiple Sourcing

It is imperative that any CEN RTTT Standard for AFC allows for multiple sourcing by the user. This implies that the technology/technique must either be open and free from patent, or that patents must be released to the public domain, or readily available to all applicants on declared and reasonable commercial terms.

2.5 Security/Privacy

Security and Privacy provisions may be required within AFC systems according to the differing requirements of separate applications and are therefore in the domain of AFC applications and will be developed within WG1 as required. If encryption or scrambling is provided by the application interface layer, it may be used to protect privacy in certain cases.

2.6 Reliability

Following the summary of requirements is an informative annexe that shows some of the rationale behind our requirements. Whilst not forming requirements at the interface level, this annexe is included as it may be helpful in your considerations and understanding some of our thinking.

3. Specific PERFORMANCE REQUIREMENTS FOR AFC

3.1 Discussion

Because for a user of and AFC service the system only has to function when it passes a service point, reliability as function of time is not so much of interest. The user is more interested in reliability per passage, or per transaction as we shall call it. The system operator is interested in reliability per passage and the average availability of the system.

The tables given below provide, where possible, a simple classification of requirements, however, it is recognised that the requirements will differ in different situations, and that some situations will require higher or lower standards of performance. Where this has been identified these requirements are shown as different ‘Classes’. It is not appropriate that the ‘highest’ class of performance should be required in all cases because there is usually a significant cost overhead in so doing. By adopting the principal of ‘classes of requirements’ operators may, when writing their specifications, specify the appropriate ‘class’ of requirement for their system.

In respect of vehicle speeds, these are shown at different ‘levels’ to provide the same flexibility of approach, and yet to recognise that different speed requirements are a fundamntal parameter to an AFC system as opposed to a particular requirement.

3.2. TRAFFIC CONDITIONS

Requirement 1: **The Automatic Fee Collection System shall work reliably for any licensed vehicle in Europe. The Automatic Fee Collection system shall be interoperable in all traffic conditions that may be reasonably expected to be encountered anywhere in Europe.**

Note: In the following tables:

1.Sizes of vehicles are valid for motor vehicles with more than three wheels

2.The lateral minimum distance between vehicles in a single lane configuration is due to the physical separation of lanes,

3. The 'low' beacon mounting heights relate to post mounted beacons (not overhead mounted).

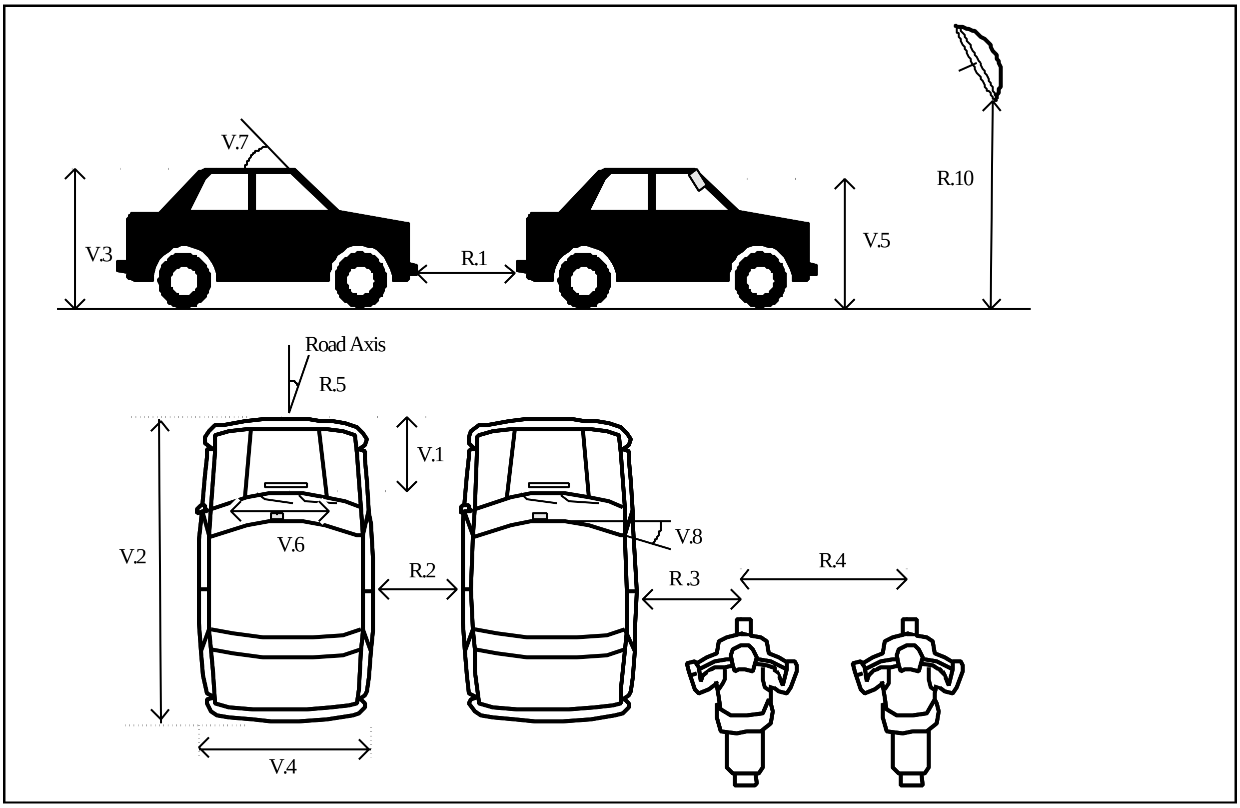

Table 1 Schematic drawing of the vehicle and road parameters.

Example: The traffic conditions, divided in vehicle and road parameters, which are estimated to define the relevant aspects of these licensed vehicles in requirement Table 1B are listed below.

The number of each parameter (excluding convoi exceptionel) corresponds to the tables below.

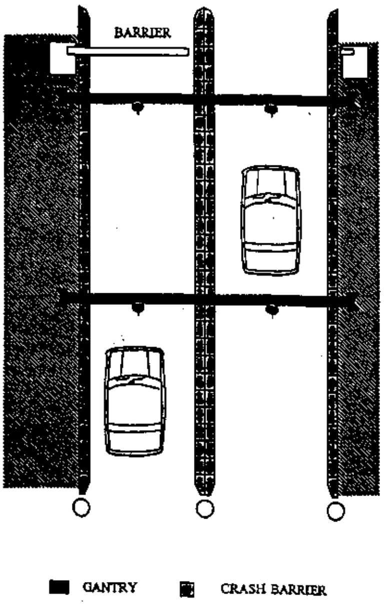

Table 2 Schematic: Single Lane Configuration

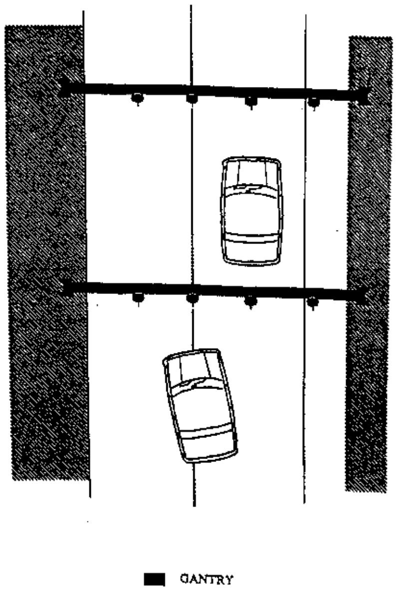

Table 3 Schematic: Multi-lane Configuration

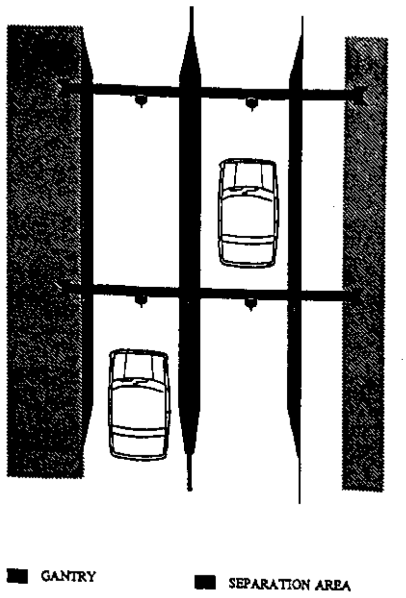

Table 4 Schematic:Pseudo Multi-lane Configuration

Table 5

Normal Traffic Conditions **REQUIREMENTS: Position of OBE and operating speeds**				
No.	**Parameter**	**Min**	**Typical**	**Max**
V.5	Mounting height of the OBE Antenna[1]:	0.70 m	1.30 m	3.00 m
V.6	Lateral mounting of the OBE[1] Antenna on windscreen [1][3]:	-15cm	middle	15cm
V.9	SPEED OF VEHICLES :			
	LEVEL 1:			
	Charging Limits:	0 Km/h		160+ Km/h
	Enforcement Limits:	0 Km/h		200+ Km/h
	LEVEL 2:			
	Charging Limits:	0 Km/h		160 Km/h
	Enforcement limits:	0 Km/h		200 Km/h
	LEVEL 3:			
	Charging Limits:	0 Km/h		90 Km/h
	Enforcement Limits	0 Km/h		120 Km/h
	LEVEL 4:			
	Charging Limits:	0 Km/h		60 Km/h
	Enforcement Limits:	0 Km/h		90 Km/h
	LEVEL 5:			
	Charging Limits:	0 Km/h		30 Km/h
	Enforcement Limits:	0 Km/h		50 Km/h

Table 6

Normal Traffic Conditions : **EXAMPLES: Vehicle Parameters**					
No.	**Parameter**		**Min**	**Typical**	**Max**
V.1	Bonnet length:		0 m		
V.2	Length [1] of the vehicle[2]:		2.5 m		24.0 m
V.3	Height [1] of the vehicle:		1.0 m		4.3 m
V.4	Width [1] of the vehicle:		1.4 m		2.6 m
V.7	Angle [3] of wind-screen (from horizontal plane)	Cars	0°		45°
		Small trucks and vans	40°		60°
		Trucks, Bus & touring cars	60°		90°
V.8	Angle [3] of windscreen (from vertical plane)		45°	0°	45°

[1]Measured from the road surface

[2]Sizes of vehicles are valid for motor-vehicles on more than three weels.

Table 7

TRAFFIC CONDITIONS/ROAD PARAMETERS					
Single Lane Configurations					
No.	**Parameter**	**Minimum**		**Typical**	**Maximum**
R.1	Longitudinal distance between two cars [4] CLASS 1	Km/h 0-60	0.5 m		
	CLASS 2	Km/h 60-90	1.0 m		
	CLASS 3&4 .	Km/h 90+	4 m		
R.2	Lateral distance between two vehicles	1m[3]			
R.3	Lateral distance between a car and a motorbike	1m			
R.4	Lateral distance between two motorbikes	1m			
R.5	Driving angle of a vehicle	-10°		0°	10°
R.6	Width of a lane	2.8 m		3.5 m	5.0 m
R.7	Direction of traffic	one way			
R.8	Number of vehicles in paralell	0			
R.9	Traffic flow per lane ('peak' as vehicle/hour) [1]	0		1500	3000
R.10	Mounting height of the beacon antenna	1.3 m[4]		5.5 m	
R.11	Lateral distance between OBEs of a car and a motorbike	Overtaking not allowed			
R.12	Lateral distance between OBEs of two motorbi-kes	Overtaking not allowed			
R.13	OBE position measurement accuracy	not relevant			

[3] Fixed distance between vehicles due to physical separation of lanes.

[4] The low beacon mounting height refers to post mounted beacons rather than overhead mounted ones.

Table 8

TRAFFIC CONDITIONS/ROAD PARAMETERS					
Multi Lane Configurations					
No.	**Parameter**		**Minimum**	**Typical**	**Maximum**
R.1	Longitudinal distance between two vehicles		as single lane		
R.2	Lateral distance betw-een two cars	0-60 Km/h	0.5 m		
		60+ Km/h	1 m		
R.3	Lateral distance be-tween a car and a motorbike	0-60 Km/h	0.5 m		
		60+ Km/h	1 m		
R.4	Lateral distance between two motorbikes		1 m		
R.5	Driving angle of a vehicle	0 Km/h 60 Km/h	-40° -40°	0° 0°	40° 40°
		160 Km/h	-10°	0°	10°
R.6	Width of Pavement		3.5 m	10m	30 m
R.7	Direction of traffic		one way, with lane changing		
R.8	Number of vehicles in parallel		1	2 & 3	7
R.9	Traffic flow per lane (vehicles/hour)		0	1500	3000
R.10	Mounting height of the beacon		5.0 m	5.5 m	
R.11	Lateral distance between OBEs of a car and a motorbike		1.5 m		
R.12	Lateral distance between OBEs of two motor-bikes		1 m		
R.13	OBE position measurement accuracy		t.b.d.	+/- 0.5 m	t.b.d.

Table 9

TRAFFIC CONDITIONS/ROAD PARAMETERS

Pseudo-Multi Lane Configurations

No.	Parameter		Minimum	Typical	Maximum
R.1	Longitudinal distance between two vehicles		as single lane		
R.2	Lateral distance between two cars	0-60 Km/h	0.5 m		
		60+ Km/h	1 m		
R.3	Lateral distance between a car and a motorbike	0-60 Km/h	0.5 m		
		60+ Km/h	1 m		
R.4	Lateral distance between two motorbikes		1 m		
R.5	Driving angle of a vehicle	0 Km/h	-10°	0°	10°
		60+ Km/h	-10°	0°	10°
R.6	Width of a lane		3.5 m	3.5 m	5.0 m
R.7	Direction of traffic		one way, without lane changing		
R.8	Number of lanes		2	2 a 3	7
R.9	Traffic flow per lane (vehicles/hour)		0	1500	3000
R.10	Mounting height of the beacon		5.0 m	5.5 m	
R.11	Lateral distance between OBEs of a car and a motorbike		1.5 m		
R.12	Lateral distance between OBEs of two motorbikes		1 m		
R.13	OBE position measurement accuracy		t.b.d.	+/- 0.5 m	t.b.d.

REQUIREMENTS: OPERATIONAL CONSTRAINTS

The reliability requirements on system level (2&3) are formulated in a qualitative way, not quantitatively.

A. Reliability, Availability, Maintainability.

Comment: *Requirements for reliability are derived from the outside inwards. First, the requirements on overall system level (where the system is looked upon as a 'black box' between one end (e.g. user) and the other (e.g. operator)) have to be formulated. Second, every link in this end-to-end chain has to adhere to specific link requirements. The Dedicated Short Range vehicle-beacon Communication is one of the links in this chain. Clearly, the sum of the link requirements will have to be with the requirement at system level.*

Comment: *Only those reliability requirements on the DSRC are given which are assumed to be relevant for compatibility. Note that since the DSRC is only one of the links in the chain, this implies that assumptions on the reliability of other links in the chain have been made.*

A1. System level Reliability, Availability and Maintainability.

Requirement 1: Reliability. :User

: The Automatic Fee Collection System shall be reliable.

Comment: *On system level, to limit the number of unjust financial consequences for the user to an absolute minimum. The number of inconveniences to the user shall be as low as possible.*
The system is reliable for the user when they can use it for all their trips and when it is credible, i.e. he will be charged correctly once for each individual passage.

Requirement 2: Reliability. :Operator

***:* The Automatic Fee Collection System is reliable when all users complete their transactions before leaving the network.**

Comment:*The system (requirement 2) is not the cause of lost revenues.*

Comment:***Operator****: Maintainability of the system, and specifically the ground equipment, determines the availability of the system.*

Requirement 3 : **Availability and Degradation.**

The AFC system shall allow the operator to achieve a very high availability.

Comment**:*Operator:*** *The system (Requirement 3) should enable graceful degradation in the event of component failure.*

A2. Transaction level Reliability, Availability and Maintainability.

Requirement 4: **Transaction Error Rates (Detected Failures).**

The probability that the DSRC fails, with the failure being *detected*, shall not exceed 10^{-5} per transaction.

Requirement 5**:** **Undetected Failures.**

The probability that the DSRC fails, with the failure remaining *undetected*, shall not exceed 10^{-8} per transaction.

A2.1 Road Side Equipment (RSE) Reliability, Availability and Maintainability.

Requirement 6: **Availablility:**

On transaction level, the availability of the RSE shall not be worse than 99.5%.
The RSE shall allow operation 24 hours a day, seven days a week.

Comment: *Failures to be taken into account include hardware break downs and incorrect software operation, i.e. anything that results in loss of functionality. It is assumed that adequate provision is made for 'redundancy' by the operator.*

Requirement 7 : **Maintainability:**

The RSE shall be designed in such a way as to facilitate maintenance (accessibility, modularity).

A2.2 On-Board Equipment Reliability, Availability and Maintainability.

Requirement 8: **Reliability:**

The failure rate of the On board DSRC equipment shall be as classified in the following table.

Table 10

MTBF	
CLASS a	**$2x10^5$**
CLASS b	**10^5**
CLASS c	**$0.5x10^5$**

Requirement 9: **Maintainability:**

The On-Board DSRC equipment (excluding other OBE equipments and power source) shall not require maintenance.

Requirement 10 **Availability:**

The On-Board Equipment shall have a lifetime of at least 5 years (including non-changeable batteries).

Comment:*In case (Requirement 10) the OBE power is supplied by the vehicle, lifetime of the OBE shall be a minimum of 5 years.*

Requirement 11 **Minimum Lifetime of OBE.**

The minimum lifetime of the OBE shall be as determined in the tables below. In the case of using an exchangeable battery in the OBE, lifetime of the battery shall be as determined in table 13 below.

Table 11

LIFETIME	OBE
CLASS 1	15
CLASS 2	10
CLASS 3	5

Table 12

LIFETIME	TRANSACTION CYCLES PE YEAR
CLASS A	20,000
CLASS B	10,000
CLASS C	4,000

Table 13

LIFETIME	BATTERY	Based on a minimum of 2000 full transactions per year
CLASS 1	10	
CLASS 2	5	
CLASS 3	2	

Comment: *Manufacturers shall be responsible for ensuring that where an OBE dwells within the read range of a beacon that this shall not degrade below the class read minima requirements.*

B. Environmental Conditions

Requirement 12: **Environmental Conditions.**

The Automatic Fee Collection System shall be able to operate under the following conditions:

- **for the RSE (Road Side Equipment) the conditions as specified in the table below. Refers to 'IEC 721-3-4 Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Stationary use at non-weather protected locations', with the following addition:**

  : If applicable, the RSE shall be able to operate in environment class 4Z8.

  : Heat radiation class 4Z2 may occur in special cases and should be considered where applicable.

  : Wind load on gantry, post and other externally mounted equipment to IEC 721-3-4, 4Z3 up to 4Z5 according to local conditions.

Table 14
ROAD SIDE EQUIPMENT

CLASS 1	**IEC 721-3-4**	**4K2/4Z7/4B1/4C2/4S3/4M4**
CLASS 2	**IEC 721-3-4**	**4K3/4Z7/4B1/4C2/4S3/4M4**

- for the OBE the conditions as specified in the table below. Refers to 'IEC 721-3-5 Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Ground vehicle installations'.

Table 15
ON BOARD EQUIPMENT *** Please see also IEC 721-3-5 Footnotes 1&2 (p.15) re: Solar Radiation**

CLASS 1	**IEC 721-3-5**	**5K2/5B1/5C1/5S1/5F1/5M2**
CLASS 2	**IEC 721-3-5**	**5K3/5B1/5C1/5S1/5F1/5M2**

Comment:*The above requirement (12) applies to active operation (i.e. performing transactions) as well as passive storage of data (i.e. in between transactions). All requirements refer to the outside environment of the equipment, not to the conditions inside the equipment housing.*

Comment:*For motorbikes, different requirements will be applicable.*

C. Attenuation

Requirement 13: **Where Reading Through Windscreens:**

The Automatic Fee Collection system shall be able to perform transactions involving any normal licensed vehicle with windscreens presenting a global maximum two way attenuation of *XXXX dB.**

(*To be agreed in discussion between WG1 & WG9).

Table 16
Example Assuming Antenna reading through Windscreen

Source	**Attenuation**	
	Best Case	Worst Case
Normal OBE to windscreen misalignment losses	0 dB	3 dB
Propagation through (normal) windscreen material	3 dB	5 dB
Dirt, snow, water, rain, hail, sleet, fog, etc. on the windscreen and in the air environment	0 dB	4 dB
Multipath and back-scatter	0 dB	2 dB
Total	**3 dB**	**14 dB**

The attenuation values given in this example assume:

- Air environment propagation attenuation treated separately,
- Communication in the 5.795-5.815 GHz band,
- No extreme windscreen attenuation,
- Adequate alignment of On-Board Equipment to the wind-screen.

Comment: *The above table does not take into account special factors such as windscreens with special coatings for attenuation of sunlight or metal shields for windscreen de-frost.*

Requirement 14: **Attenuation:**

The Automatic Fee Collection System shall be able to operate under conditions where one vehicle has worst case attenuation whereas the adjacent vehicle has best case attenuation.

Example: Under the assumptions of the example of requirement 13, this would amount to a difference in attenuation of adjacent vehicles of 11 dB.

Requirement 15: **Impaired Communication:**

The Automatic Fee Collection System shall be able to perform transactions even when the communication is disturbed or temporarily impaired by windscreen wipers.

D. EM disturbance and radiation

Requirement 16: **Electromagnetic Disturbance :**

The Automatic Fee Collection System shall be able to perform transactions in an environment with electromagnetic disturbance in accordance with 'IEC 801'[10]., EN 50081.

Requirement 17: **CEPT:**

The AFC shall use frequencies in accordance with CEPT Recommendation 'Decision of CEPT/ERC February 1990 allowing frequency band 5.795-5.805 GHz for PAN-European RTI applications (additional 5.805-5.815 GHz for specific local applications)'.

E. Security

Comment: *Within the AFC system, fraud is defined as 'getting the service without paying for it'. The key issue of fraud, as compared to other threats, is that it brings financial gain to the person frauding.* ***Fraud is considered an application issue rather than a 'link' issue, and therefore not relevant for WG9.***

F. Vandalism and sabotage

Comment: *Vandalism is defined as destroying or damaging materials and/or data on a small scale without having a real direct objective (react to its own frustration could be an indirect objective).*

Requirement 18: **Destruction of Equipment :**

The Automatic Fee Collection System shall provide reasonable protection against vandalism and sabotage, through destruction of equipment.

G. Safety

Requirement 19: **Emissions:**

The electric or magnetic components of any electric or magnetic fields produced by the Automatic Fee Collection System shall not exceed the levels as specified in 'EN 60215 Safety requirements for radio transmitting equipment, 1987 (IEC 215)'.

Example: Requirement 19 implies that transmitted electric and magnetic fields shall not exceed 200 V/m or 0.5 A/m, respectively over the frequency range 30 MHz to 30 GHz. This approximately corresponds to a radiation power density of 100 W/m^2 (10 mW/cm^2) and applies to distance greater than 5 cm from accessible surfaces of the equipment.

Comment:*User and operator safety requirements concerning explosion danger, unsticking etc. are to be defined.*

H. Privacy

Comment:*Privacy is defined as 'the right of each individual to determine the amount of personal information he/she is willing to share with others'.*

Requirement 20: **Privacy:**

The Automatic Fee Collection System shall provide a system option to enable the protection of the user against unwanted identification of the presence of a specific user. The system may offer other altematives of enjoying the service which are not anonymous.

Comment: *Where the privacy of a system is not inherrently 'Anonymous' it shall be provided by other means such as data protection legislation or software design.*

I. Flexibility and Expansion

Requirement 21 ***:*** **Additional Services:**

The Automatic Fee Collection System shall be able to support integration of additional services.

Comment: *The AFC is primarily targeted for services such as toll and road pricing. Secondly, it shall cater for services such as parking, ferry, public transport. The requirement implies that the number of services shall not be restricted by definition. If, in future, the overall AFC system concept would allow another service to be covered as well (e.g. payment for gasoline), this shall be possible in principle.*

Requirement 22: **Additional Road Traffic and Transport Telematics:**

The Automatic Fee Collection System shall be able to support integration of additional Advanced Transport Telematics applications.

Comment: *It is envisaged that, in future, different Road Traffic and Transport Telematics applications will make use of the same equipment. The DSRC equipment (transponders, beacon, (part of) the OBE) may for instance be used for fleet management as well as for AFC. The requirement states that this shall be possible in principle.*

Requirement 23: **Multiple Functions:**

The Automatic Fee Collection System shall be able to support more than one combination of optional functions. The choice of functions is made in the actual technical implementation (the 'product'). These products may thus range from simple to more complex functionality.

Example: Examples are different user interfaces such as display functions etc.

Requirement 24: **Operational Constraints:**

All European Standard Automatic Fee Collection System Fixed Equipment shall have the capacity to understand all European Standard transponders, albeit of different capability.

Comment: From the users point of view, he requires functionality wherever he uses his vehicle. Because of the different levels of complexity of different solutions, that functionality may be at a lower level than is achievable within his home territory, but should be adequate to achieve the minimum requirements of the Standard unless specifically excluded and notified to the user. This implies 'upwards interoperability' where the more simple devices can be understood by the more complex, and the more complex can make themselves understood by simple systems.

J. User friendliness

Requirement 25 : **Mounting OBE:**

The technology adopted for the Automatic Fee Collection System shall not preclude On-Board Equipment product which can be mounted by the road user himself, without any aid from an expert.

K. Costs

Requirement 26 : **Upwards Compatibility:**

The Automatic Fee Collection System shall allow products which are commercially competitive with existing systems.

Example: Requirement 27 may imply that the system will at least allow a product which can compete with existing tag/AVI equipment.

Requirement 28: **Competitive Purchasing:**

The AFC Standard shall allow 'open' purchase of equipment, i.e. shall allow 'multiple sourcing' of both On-Board and Fixed equipments. The use of the Standard shall not be hindered by patents. If patents do apply, licenses against pre defined nominal fees will have to be granted in advance.

ANNEX 1: Performance and Reliability. A discussion Document supporting the work of WG1 SG2

1 *This Annexe gives detail of much of the rationale behind the performance, reliability and availability requirements for AFC , and for a DSRC link to support AFC.*

2 RELIABILITY AND AVAILABILITY

2.1. DEVIATION FROM SPECIFIED BEHAVIOUR

The required behaviour of a system is laid down in its specification. During the design process this specification is transformed into an implementation. After checking whether the system performs according to its specification the system starts its operational life.

During its operational life a system can fail (i.e. perform differently from its specification) due to several causes, which can be divided into the following three categories:

a. design errors,
b. failing components and extreme external environmental conditions,
c. unspecified human (mis)behaviour.

2.1.1 Design errors

Design errors occur during the process of transforming a specification into an implementation. For ease of ourselves we also take the errors during the requirements analysis into account as design errors. Design errors can occur in hardware as well as software. Counter measures that can be taken to minimise design errors can be divided into the following four categories:

A. Formal specification and design methods,

B. Fast Prototyping,

C. Multiple mutually independent designs (N-version programming) or implementation of extra intelligence for exceptional cases (Exception Handling),

D. Testing.

2.1.2 Failing components and extreme external environmental conditions

Hardware components can deviate from their specified behaviour due to internal causes (e.g. ageing, wear-out) or external causes (e.g. radiation or environmental conditions). This failing behaviour can be random and of short duration (transient fault), can repeat itself irregularly (intermittent fault) or can have a permanent nature (permanent fault). Technical measures that can be taken to minimise the consequences of failing components can be divided into the following two categories:

A. Fault-avoidance: worst case design using ultra-reliable components,

B. Fault-tolerance: redundancy of system components; test and diagnosis procedures during operational life for preventive maintenance and timely repair.

In systems that do not only involve technical means but also an organisation of people performing certain essential tasks, also organisational measures can be taken against failing technical system components. Consequently, the system as a whole can make a robust impression despite failing technical components.

2.1.3 Human (mis)behaviour

Systems can fail due to users or/and operators that do not perform as specified. This misbehaviour can be by accident or can be on purpose. Minimisation of misbehaviour by accident can be realised by user-friendly well-designed and documented user and operator procedures. On purpose misbehaviour can be divided into the following two categories which can each be divided into two subcategories:

A. *No profit objective:*

A.1: **Vandalism:** destroying or damaging materials and/or data on a small scale without having a real direct objective (react to its own frustration could be an indirect objective).

A.2: **Sabotage:** destroying or damaging materials and/or data on a large scale with the objective to cause financial damage to the system owner.

B. *Profit objective:*

B.1: **Burglary:** acquiring materials or/and data.

B.2: **Fraud:** manipulating the system with commercially exploitable or personal profit as objective.

In general measures against the above mentioned failure causes are called **security** measures.

2.2. DEFINITION OF RELIABILITY AND AVAILABILITY

2.2.1 Reliability

In general the reliability R(t) of a system is defined as a function of the time t:

The reliability R(t) is the conditional probability that a system functions correctly in time interval [0,t] given the system did function correctly at time 0:

R(t) = Prob(system functions correctly in time interval [0,t] | systems did function correctly at time 0).

In practice it turns out that the process of failing hardware components can be very well described by a Poisson process. The Poisson probability density function p(t) is a negative exponential density function:

$$p(t) = \lambda(t)e^{-\Lambda(t)},$$

where

$$\Lambda(t) = \int_0^t \lambda(x)\, dx.$$

The function $\lambda(t)$ is called the failure rate. In general this function has the shape of a bath-tub (see fig.1)

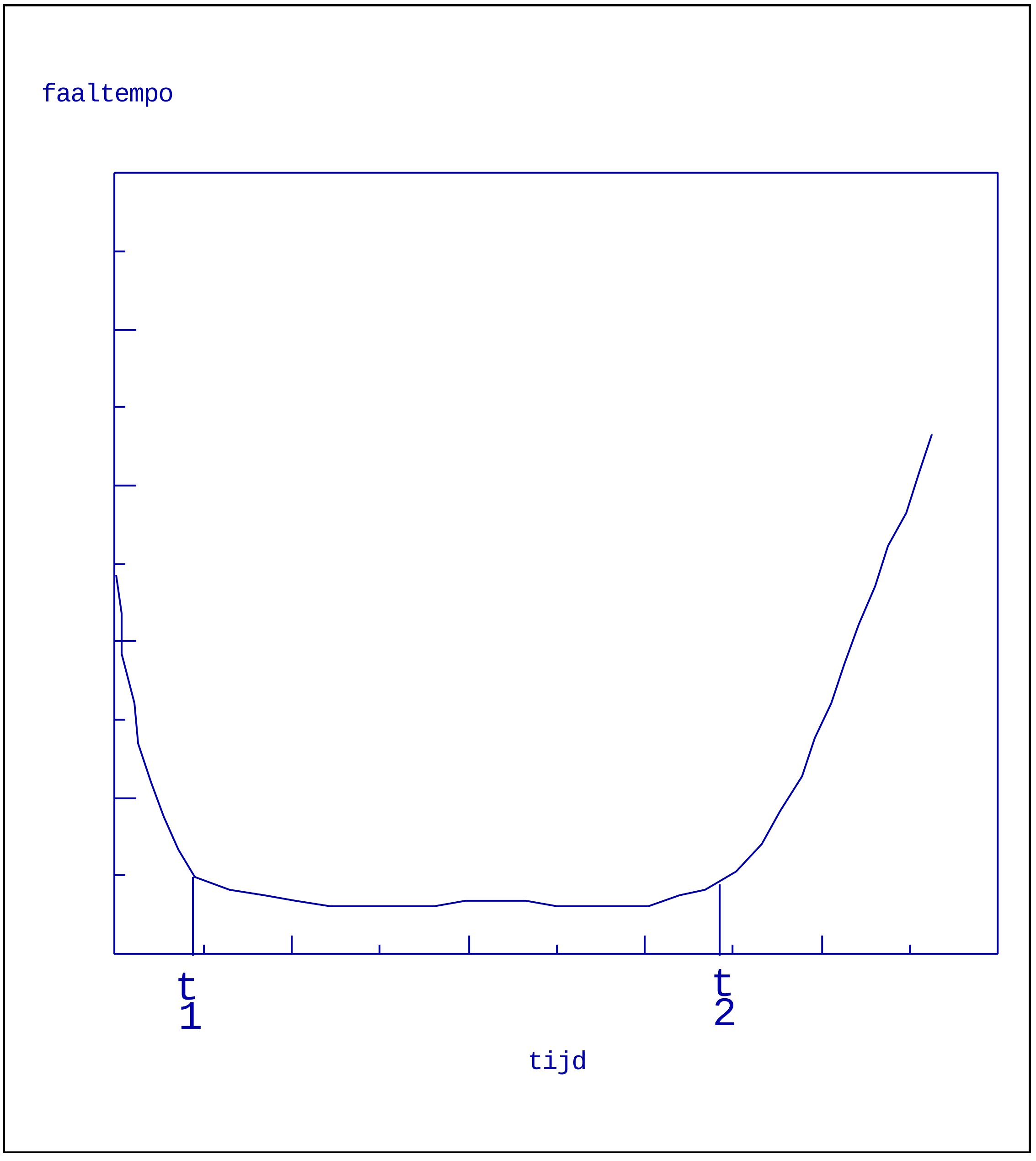

Figure 1: Bathtub Curve: failure rate of a component.

In the beginning of the life of a component (the time interval [0,t_1]) the failure rate is quite high. This interval is called the infant-mortality interval. After time t_1 the bad components have disappeared and the components that are still alive have a relatively constant failure rate. At a certain moment in time t_2 the failure rate is going to increase due to ageing and wear-out causes.

If we now put the operational life of a component (as is normally done) in the interval $[t_1,t_2]$ then we can consider the failure rate to be constant:

$$\lambda = \lambda(t).$$

The probability density function p(t) then equals

$$p(t) = \lambda e^{-\lambda t},$$

and the cumulative probability P(t) that a component does not function any more at time t equals

$$P(t) = \int_0^t \lambda e^{-\lambda\tau} d\tau = 1-e^{-\lambda t}.$$

Hence, the reliability function R(t) is equal to

$$R(t) = e^{-\lambda t}.$$

If a system is composed of n components with failure rates $\lambda_1,\lambda_2,\ldots,\lambda_n$ respectively and the system functions correctly if and only if all components function correctly, then the reliability R(t) is the product of the reliability functions $R_i(t)$ of its components,

$$R(t) = R_1(t)*R_2(t)*....*R_n(t),$$

and hence the failure rate λ of the system is the sum of the failure rates λ_i of its components,

$$\lambda = \lambda_1 + \lambda_2 + ... + \lambda_n.$$

In practice this estimate of the overall system failure rate is a bit pessimistic, because the failure rates of the components are not completely mutually independent, but somewhat correlated (e.g. for the influence of the temperature). But at least the above estimate is safe.

2.3 Availability

The availability A(t) of a system as function of the time t is defined as the probability that the system is operational at time t. In practice, we use the average availability of the system, which is defined as the fraction of time that a system is operational.

We can distinguish between :

- the availability of an AFC system from the operators view and
- the availability of the DSRC link and services from the mobile vehicles view.

The highest priority on the availability is on the real time communication of the DSRC and is descending (gantry-local system-central system) to the lowest priority to an off-line communication between for example two clearing stations of different operators.

2.3.1. Operators view

The availability for the DSRC, the gantry controller and the enforcement system must be >= xx %, where xx% is as near 100% as is practicable to expect..

The availability of the communication between the beacon and the central system of the operator depends on the tolling scenarios :

> This could have a high priority in closed tolling scenarios, because there is a need to compare the information's of the transactions (entry / exit ticket) , and a low priority in open tolling scenarios with off-line communications.

The availability of the central station and the communication between operators and / or clearing stations has a low priority, because its most of the time off-line and the need can be influenced by the storage space of the different hardware equipments.

2.3.2. Mobile vehicles view

The availability of the DSRC must be >= xx %, where xx% is as near 100% as is practicable to expect., and is very important to the acceptance of the whole AFC system by the vehicle user.

To get an optimal availability of the DSRC link there are the following requirements:

Approach phase:

- Short cyclic replay of the starting sequence and optimised length of the message from the gantry (BST,...), to wake up and / or trigger the OBE, which could enter the short communication zone at every step of the starting sequence.

- Getting the support of the BST on the offered services, to make a choice which service will be used by the vehicle.

All phases:

- Time optimised up and down link communication and protocol

- Optimised management of the distinction of different OBEs in the same communication zone (especially in multilane application).

- Replay of up and down link communication if any failure occurs.

2.4 Mean Time To Failure en Mean Time To Repair

The Mean Time To Failure (MTTF) of a system is defined as the average time that expires before a system fails, given it did function correct initially:

$$MTTF = \int_0^\infty R(t)dt = \int_0^\infty e^{-\lambda t}dt = 1/\lambda.$$

The Mean Time To Repair is the average time needed to repair a system, that is the time that expires between system failure and bringing up the system again.

Then the (average) availability of the system equals:

$$A = MTTF / (MTTF + MTTR).$$

2.5 Lifetime

The lifetime of a system is defined as the maximum time period that the system will be used in operation. Hence it is a deterministic defined period, in contrast to the time to failure of a system which has a statistical character. Nevertheless the lifetime of a system will always be defined to be less than its MTBF. Typically the lifetime of a system is equal to the time where the failure rate changes its constant behaviour into a increasing one (i.e. time t_2 in figure 1).

.

3. RELIABILITY REQUIREMENTS

3.1 Level 1

User

From the viewpoint of the user, an AFC transaction that fails could lead to

a. unjust financial consequences if the fault is not detected by the system and the user is blamed for it,

or

b. inconvenience because the transaction does not take place correctly the first time, but only after some extra actions are taken by the user (and the operator).

Examples of user requirements on level 1:

The probability that a transaction leads to unjust financial consequences should not exceed 10^{-x}.

The probability that a transaction leads to major (to be defined) inconvenience should not exceed 10^{-x}.

The probability that a transaction leads to minor (to be defined) inconvenience should not exceed 10^{-x}.

The classification of inconvenience can take place after definition of the exact automatic AFC service provision and the extra organisational procedures needed if automatic service provisions did not work.

Operator

From the viewpoint of the operator, an AFC transaction that fails could lead to:

c. loss of income if recovery is not possible,

or

d. extra operating costs if the operator has to take some extra actions to recover the failing transaction.

Examples of operator requirements on level 1:

The probability that a transaction leads to loss of income should not exceed 10^{-x}.

The probability that a transaction leads to major (to be defined) extra operating costs should not exceed 10^{-x}.

The probability that a transaction leads to minor (to be defined) extra operating costs should not exceed 10^{-x}.

It should be noted that at this level (level 1) neither a user nor an operator care which is the cause of a failing transaction. He does not mind whether the cause is in the category design errors, failing components or by accident or on purpose human (mis)behaviour.

3.2 Level 2

For a reliability analysis at level 2, we split the AFC functionality into sub processes. Sub processes to be thought of are:

- BEFORE-ACTUAL-SERVICE-PROVISION-processes:
    - installation of on-board units,
    - revaluation of balance in on-board units in ON/PRE/PP payment mode,
    - etc.

- ACTUAL-SERVICE-PROVISION-processes:
    - wake-up of the on-board unit by the roadside unit,
    - presentation of required information by the on-board-unit to the road side equipment,
    - charging of the on-board unit by the roadside equipment,
    - presentation of proof of payment or subscription,
    - enforcement,
    - etc.

- AFTER-ACTUAL-SERVICE-PROVISION-processes:
    - processing of enforcement data,
    - afterwards charging, because automatic charging failed,
    - replacement of failed on-board units,
    - handling of protests.
    - etc.

This list is not complete, it only gives an idea of how to look at the problem. To any process described a reliability requirement can be set, so that if these are fulfilled also the reliability requirements at level 1 are satisfied. Therefore relations between level 1 and level 2 reliability requirements should be determined.

Example of a requirement at level 2:

The probability that the enforcement does result in non-useful data should not exceed 10^{-x} *per transaction.*

3.3 Level 3

Sub processes at level 2 are composed of system components (at level 3). Components to be thought of are:

- the user
- on-board unit (transponder + smart card if appropriate)
- revaluation equipment
- roadside equipment
  - antenna
  - open air interface (protocol)
  - camera
  - road-side computer
  - operating software
  - detection and localisation equipment
- central computer
- central database
- the operator
- communication network
- etc.

Sub processes at level 2 use certain of these level 3 components to perform their task. So dependency relations could be defined, as well as the consequences of failures of level 3 components for level 2 sub processes. The reliability requirements for level 2 sub processes could now be translated into reliability requirements for level 3 components.

For system failures caused by component failures due to wear-out or caused by accident human misbehaviour this can very well be done in a statistical way. For system failures due to design faults or due to on purpose human misbehaviour this seems more complex, if not impossible.

Failing components

Level 3 reliability requirements for system components are for example:

The failure rate of the on-board unit should not exceed 10^{-x} per hour, or in other words the MTTF should be better than 10^{x} hours.

The probability that the on-board to roadside equipment link fails should not exceed 10^{-x} per transaction.

The availability of the roadside equipment should not be worse than 99.xx %.

4. DESIGN ERRORS

Avoidance of design errors is the only measure that really helps. In addition, precaution measures should be defined and taken whenever design errors manifest themselves during the operational life of a system. If design errors are detected, measures that do not harm the user could be taken (consequently they could harm the operator). If design errors are traceable they can be corrected. So during operational life, the failure frequency of the system due to design errors should decrease in time.

5. DELIBERATE HUMAN MISBEHAVIOUR

The only measure that helps is avoidance of deliberate user misbehaviour by taking precautions such that non-profitable misbehaviour is very difficult to perform (guarding and monitoring) and profitable misbehaviour is very unlikely (i.e. with a very low probability) to become profitable (cryptographic means).

.REFERENCES

[1] Specification of the Road Situation. Ir.J.P.C.van Gennip. 23-07-1991

[2] Waterlaag en ruitenwisser, K.Dijkstra/CHL en A. van der Ree/CHL, 21-11-1991

[3] Onderzoek OBU positie em -richting, Brandes en Meurs, 31-05-91.

[4] Frequenties van voorkomen van korte tussenafstanden en volgtijden, Transpute, Gouda, 13-02-1990.

[5] ASFN contribution to CASH on reliability.

[6] CEI IEC 721-3-4, Classification of groups of environmental parameters and their severities, stationary use at non-weather protected locations.

[7] CEI IEC 721-3-4, Classification of groups of environmental parameters and their severities, ground vehicle installations.

[8] Automatic Fee Collection System Security, François Guérout, September 1992

[9] Security in Automatic Fee Collection Systems, Cash document I-012, Work Package WP 02, 12-05-1992.

[10] Electromagnetic compatibility for industrial-process measurement and control equipment, CEI/IEC 801, part 2,3,4

[11] EN 60215 Safety requirements for radio transmitting equipment 1987 (IEC 215)

[12] Kapsch AFC Requirements

[13] INTERCAI Var. Documents and principal source of text. Source:A Zandbergen.

[14] Autostrada. Telepass. AFC Requirements

[15] Thomson CSF Response to INTERCAI Documents

[16] CEN tc278 WG13 & ISO TC204 WG1 Definitions of Compatibility, Interoperability and Exchangeability

[17] The Enterprise Consultancy. Various Documents