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eVADER

Electric Vehicle Alert for Detection and Emergency Response

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Executive summary

This document will summarize the definition of the test conditions for a psychoacoustic listening test based on potential risk scenarios as well as an exemplary judgment protocol. The measurement protocols for the background noise and the risk scenarios are based on information delivered by the project partners Renault and IDIADA.

The present document provides all necessary information for performing the following activities:

- Background noise measurements for the database
- Vehicle measurements for close to accident scenarios
- Definition of general conditions for possible psychoacoustic listening tests
- Proposal for a judgment protocol for the psychoacoustic listening test

The questions proposed for the judgment protocol are strongly dependent on the objectives of the listening test. Those objectives should be defined in detail with the whole project Consortium.

Contents

1 Introduction

Quieter cars such as electric vehicles and hybrid-electric vehicles can reduce pedestrians' ability to evaluate the state of nearby traffic and consequently, have an impact on pedestrian safety. One of the objectives of the EVADER project is to propose technologies that will allow the best compromise between the potential risk of quiet vehicles for pedestrians and the quietness of residents.

WP1 aims to define the scope of the study in terms of at-risk situations for pedestrians, of situations where quiet vehicles improve the resident's comfort, of reduction of the overall level in cities, of safety management between the vehicle or driver and the pedestrian.

The specific objectives are to:

- investigate and characterize the at-risk situations for pedestrians,
- investigate and characterize different soundscapes to define psychoacoustic maskers,
- investigate and characterize different living situations for residents related to comfort perception.

With these three specifications, WP1 will propose specific scenarios for the overall project (listening tests for psychoacoustics, activation and deactivation of smart systems…).

2 Definition of test conditions

2.1 Incentive for a listening test

Due to their drive, emitted noise of electric vehicles is only depending on tire-road noise, but not anymore on the power unit. This can result in a deviation from the expected noise emission of the vehicle. Studies like [1] [2] and [3] came to the conclusion that electric vehicles may represent a higher risk in potential accident scenarios.

Several solutions for the acoustic perceptibility have been developed so far, based on different approaches. Therefore, eVader will take into account these existing pedestrian protection systems to provide a holistic view to this multifaceted problem. For developing the optimal warning signal, a series of tests have to be performed, including psychoacoustic evaluations.

2.2 Experimental design

Several studies have already dealt with this topic, like [1] [2] and [3]. Therefore, useful inputs from those documents have been incorporated in this design proposal. The following aspects should give an overview about a feasible experimental design:

2.2.1 Subject-assignment

Within the listening test, the subjects are confronted with recordings of different traffic situations via headphones. The participant's task is to mark the specific moment, when he (or she) becomes aware of the presence of the electric vehicle. Figure 1 shows an exemplary temporal event.

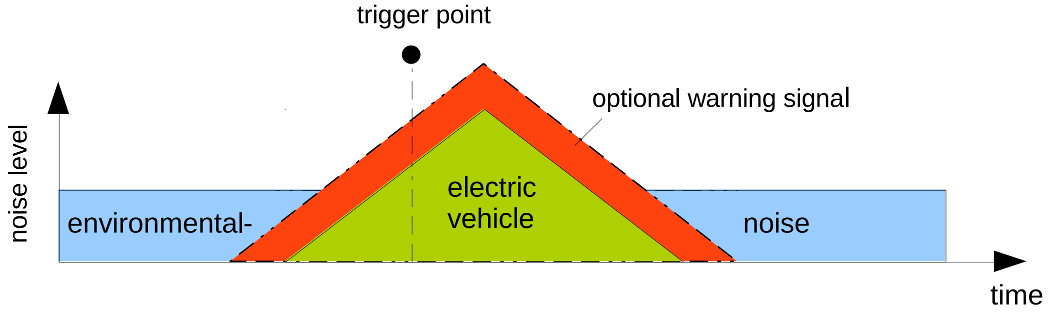

Figure 1: Temporal development of a stimulus. Once the subject has recognized the electric vehicle, it releases the trigger.

A further task could be the same like above, but now with an electric vehicle including an additional warning signal. Finally, a comparison between the results of these two tasks would give information about the improvement of perceptibility caused by the warning signal.

2.2.2 Stimuli composition

As shown in Figure 1, a stimulus consists of two or three different audio recordings – an environmental recording, a vehicle recording and an optional warning signal. How these first two binaural recordings are made is described in section 3 of this document. To obtain a variety of different stimuli, recordings of the noise environment database are combined with recordings of electric vehicles as well as ICE-vehicles, as illustrated in Figure 2.

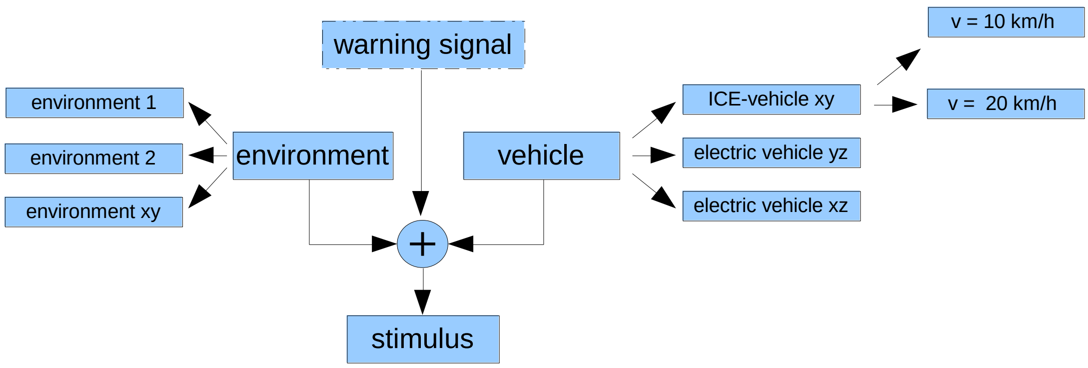

Figure 2: Composition of a stimulus – environmental background noise combined with recordings of different vehicles and an optional warning signal

In addition, every vehicle will be recorded in different scenarios – for example a vehicle turning at a crossing. The following table shows the defined scenarios, which have to be recorded for every vehicle.

Scenario	Gear	Vehicle speed (km/h)
Vehicle turning – I	2	10, 20, 30
Vehicle turning – I	3	10, 20, 30
Vehicle turning – II	2	10, 20, 30
Vehicle turning – II	3	10, 20, 30
Walking along /Backing vehicle	2	10, 20, 30
Walking along /Backing vehicle	3	10, 20, 30

Waiting to cross - I	2	10, 20, 30
Waiting to cross - I	3	10, 20, 30
Waiting to cross - II	2	10, 20, 30
Waiting to cross - II	3	10, 20, 30

Table 1: Different scenario types, which have to be performed in gear 2 and 3 at different speeds

A more detailed description of the single scenario types can be found in section 3.

2.2.3 Stimuli duration

The intended stimulus duration is between 15 and 20 seconds, but an exact length shouldn't be defined before several test stimuli have been evaluated.

2.2.4 Realism of the Stimuli

An important feedback argument of participants after the listing test in [1] was the lack of realism in the stimuli. To prevent this problem, three measures are considered when creating them:

- The desired vehicle will randomly pass from left to right or vice versa (if possible, depending on scenario). This can be easily achieved by swapping the left and the right channel auf the vehicle recording.
- A variable overall stimuli length- this offers more variety for the participant.
- The vehicle doesn't pass from one side to the other at the same time. An example would be: after starting stimulus A the desired vehicle begins to pass after five seconds, but in stimulus B the vehicle starts passing at second seven.

If these three measures are executed, only existing stimuli will be altered. This won't create new scenarios.

2.2.5 Experimental setup

Due to the requirements of an appropriate binaural playback environment, a playback system with headphones as shown in Figure 3 is preferred. A computer connected to an interface provides playback of audio files and data acquisition from the trigger. Taking into account that vision-impaired people will participate to the test, only an easy-to-use trigger should be the required instrument to complete the listening test.

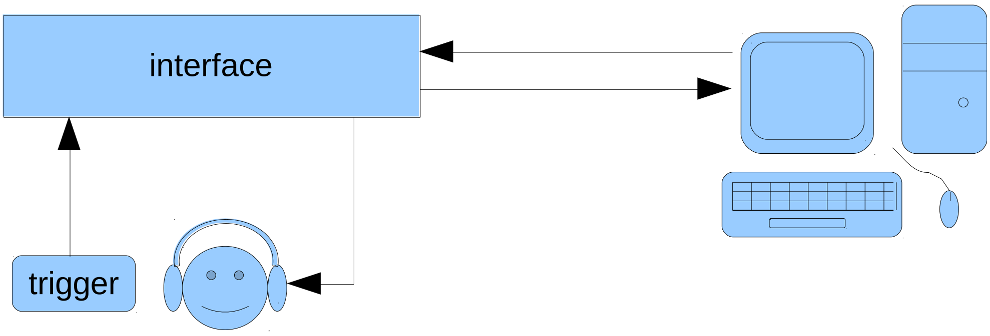

Figure 3: experimental setup – the computer provides audio playback and receives data via an interface from the trigger

Using an experimental setup like above would also minimize the requirements for the listening room. No special room acoustic is needed – only a quiet surrounding area would be advantageous.

2.2.6 Number of subjects

Depending on the considered groups of vulnerable road user and the research question of the specific listening test, a different number of people have to participate at the experiment.

2.2.7 Time schedule of the listening test

The duration of the listening test has an important impact on the quality of the test results. In general, a longer test results in a worse reproducibility of the subject's answers. Therefore, duration not longer than 30 minutes (including the judgment protocol) should be planned. Table 2 shows a first proposal for a time schedule for the psychoacoustic test.

Part of the psychoacoustic test	Duration
Explanation of the task and test run	5 minutes
Listening test	15 minutes
Judgment protocol	5 minutes

Table 2: composition of the psychoacoustic test for every participant

At the beginning of the listening test the conductor reads out the explanation of the task to ensure equal treatment of the subjects. Afterwards, the participant has the possibility to complete some test runs to get familiar with the task.

The main part of the listening test consists of the stimuli-playback. For example for a mean duration of 20 seconds per stimuli, up to 45 could be played in this time period. In the end, a judgment protocol (as desired in section 4) is filled out by the participants.

3 Measurement protocol

This section describes the measurement protocol for recording environmental noise for the database as well as the risk scenarios with ICE vehicles and electric vehicles.

3.1 Acoustic measurement of environmental sounds

3.1.1 Objectives

Every ambient noise has to be recorded with an artificial head located in two different urban environments in addition to sound level meters. The two different urban environments must be representative for this area of Europe.

The 1st site will be chosen for its low traffic volume with moderate noise level (around 40-50 dB(A)): low wind speeds, flat, clean asphalt pavement. The ambient level in the area should be representative of a quiet suburban area, which may be encountered by pedestrians.

The 2nd site will be chose for its moderate traffic volume with a noise level more representative of a city center (60-70 dB(A)). It is necessary that no cars are passing in front of the artificial head during the entire recording.

3.1.2 Instrumentation setup

Table 3 shows the technical requirements on the measurement setup

Property	
Measuring device	Dummy head from Head Acoustics or comparable
Equalization filter	Linear LIN or L0
Sampling frequency	48kHz
Recording Range	104dB
Bit resolution for recordings	24 bit

Table 3: technical requirements for the measurement setup

3.1.3 Description of measurement site

The following properties have to be determined for the measurement location:

- Address (including city and country)
- GPS coordinates (latitude and longitude)

The data will be recorded using a binaural head, positioned on the pavement in front of the road which the pedestrian is close to cross at a height of 1.5 meter over the ground.

3.1.4 Measurement conditions

- Photos and schematic representation of the measurement site (visual obstacles, intersections)
- Meteorological conditions (precipitations, wind, temperature and fluctuations during the measurement period)
- Traffic conditions
- Different sound sources, if present
- Connectors (preferable XLR)
- Microphones: frequency response (preferable)

3.1.5 Representation of results

- A-weighted level during all the measurement period
- Noise spectrum during the selected period
- File format: .wav
  An alternative format (.dat) will be also provided to have some redundancy for safety
- Naming convention for the files: YearMonthDate_City_Site_Partner

In order to have the calibration information with wav format, we have to record a calibrated sound source in wave file too (pistonphone at 1kHz at X dB for example).

3.2 Acoustic measurement of close to accident scenarios

3.2.1 Objectives

This measurement protocol describes the procedure to quantify the exterior noise detected by pedestrians in clos to accident scenarios denoted as:

- Vehicle turning – I
- Vehicle turning – II

- Walking along
- Backing vehicle
- Waiting to cross – I
- Waiting to cross –II

The geometric arrangements of these scenarios are presented in section 3.2.3

3.2.2 Instrumentation setup

Property	
Measuring device	Head Acoustics dummy head
Equalization filter	Linear LIN or L0
Sampling frequency	48kHz
Recording Range	104dB
Bit resolution for recordings	24 bit

Table 4: technical requirements for the measurement setup

3.2.3 Measurement conditions

- Photos of the measurement arrangement
- Meteorological conditions (precipitations, wind, temperature and fluctuations during the measurement period)
- Connectors (preferable XLR)
- Microphones: frequency response (preferable)

Table 5 summarizes the minimum elemental lane width for different types of roads used for different vehicles. Taking into account this information, an average elemental lane width of 3m is assumed.

Assumption	**Width of vehicle**	**Additional margins**	**Elemental lane**
Vehicle stopped or is moving with <15km/h	1.8 m	2 x 0.2m	2.2m

Big passenger cars (4x4) stopped or in narrow lanes (limit 30km/h)	2.15m	2 x 0.2m	2.55m
Big passenger cars (4x4) stopped or in normal lanes	2.15m	2 x 0.3m	2.75m
Buses and trucks in normal lanes (limit 50km/h)	2.5m	2 x 0.375m	3.25m
Roads (limit 90km/h)			≥3.5m

Table 5: minimum elemental lane width for different types of roads

The accident scenarios selected to assess the noise detected by pedestrian in close to accident scenarios are presented in Figure 4 to 8. The relative position of the vehicle, the acoustic head and the vehicle speed are also defined in the figures.

The measurement will start when the frontal part of the vehicle is on the line A-A' and it finishes when the rear part of the vehicle reaches line B-B'. Furthermore, the tolerance for distances has to be within ± 5cm and the deviation of the vehicle speed from the desired value is not allowed to exceed ± 2.5 %.

Finally, for every car the scenarios listed in Table 1 will be recorded.

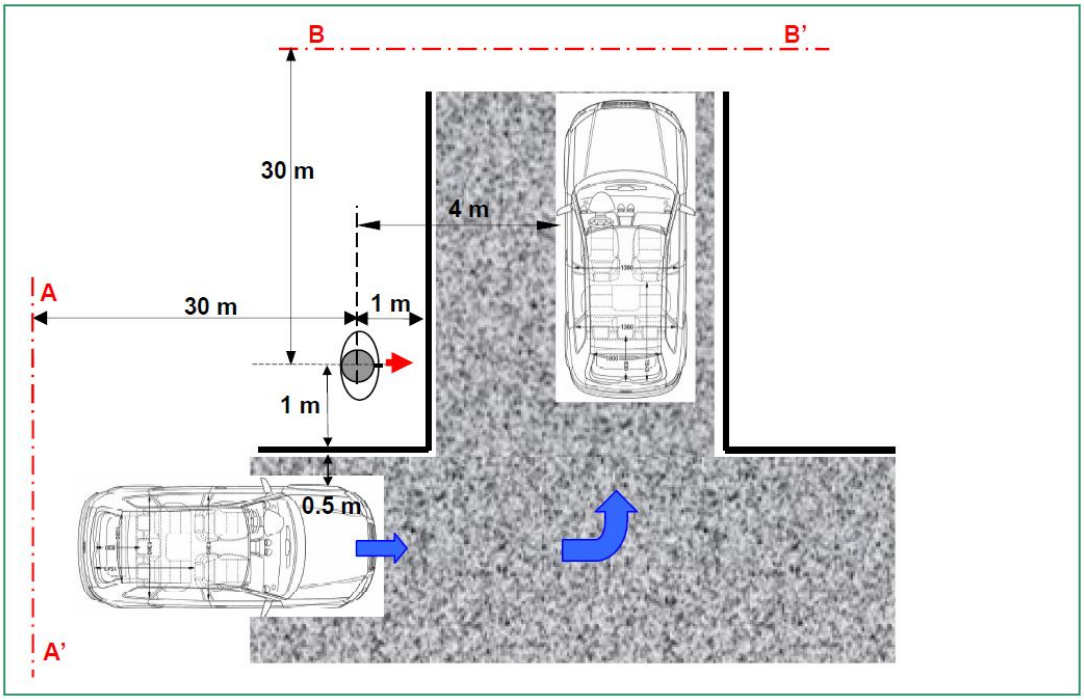

Figure 4: Vehicle turning – I. Vehicle speed: 10, 20 and 30 km/h

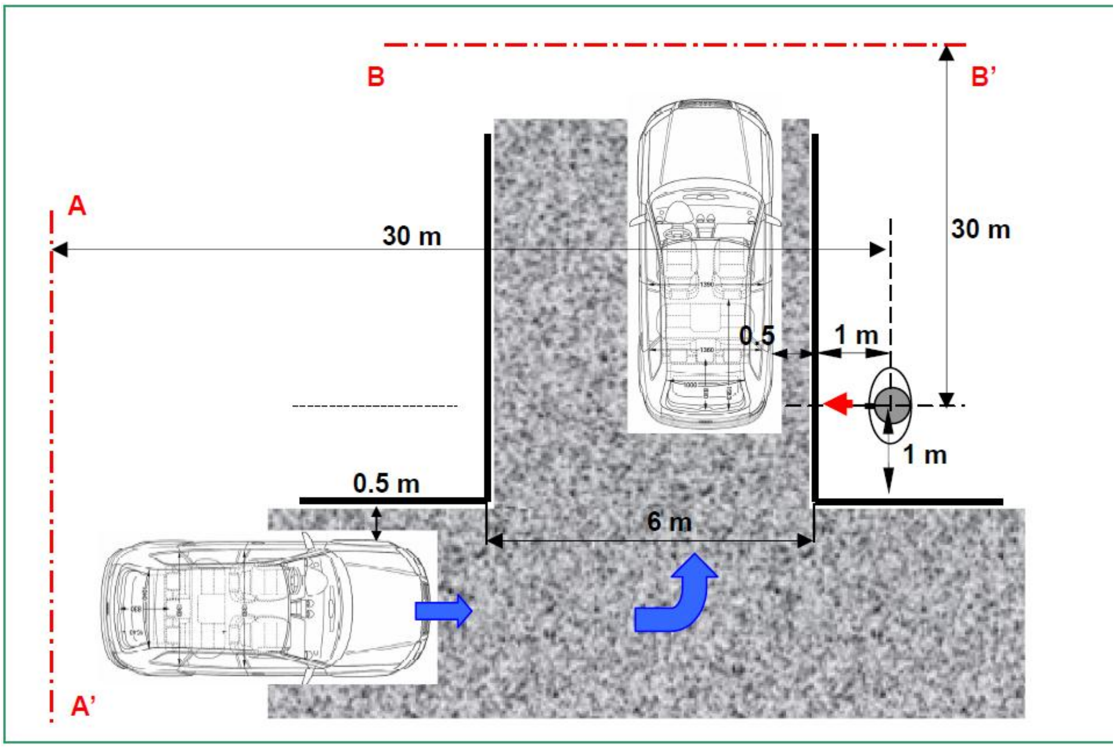

Figure 5: Vehicle turning – II. Vehicle speed: 10, 20 and 30 km/h

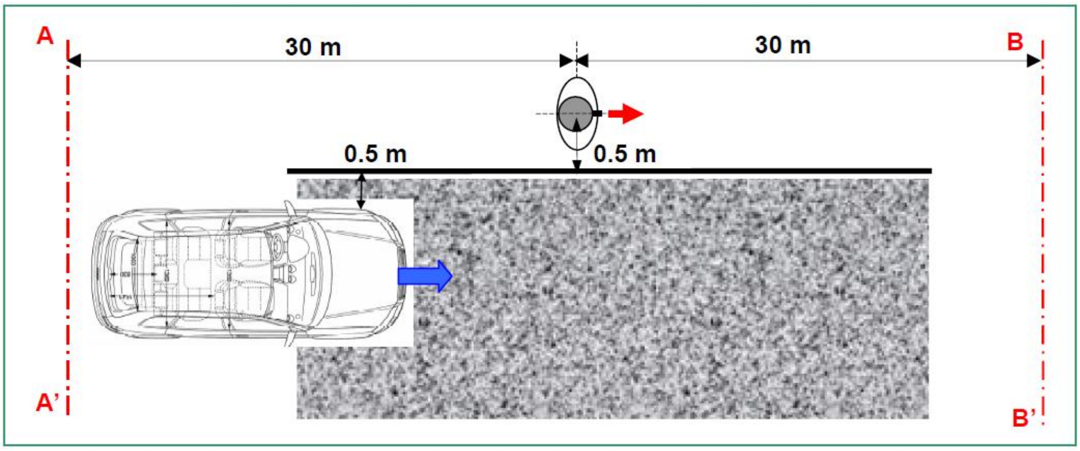

Figure 6: Walking along & backing vehicle scenario. Vehicle speed: 10, 20 and 30 km/h (setup consistent with JASIC, 2009, 1).

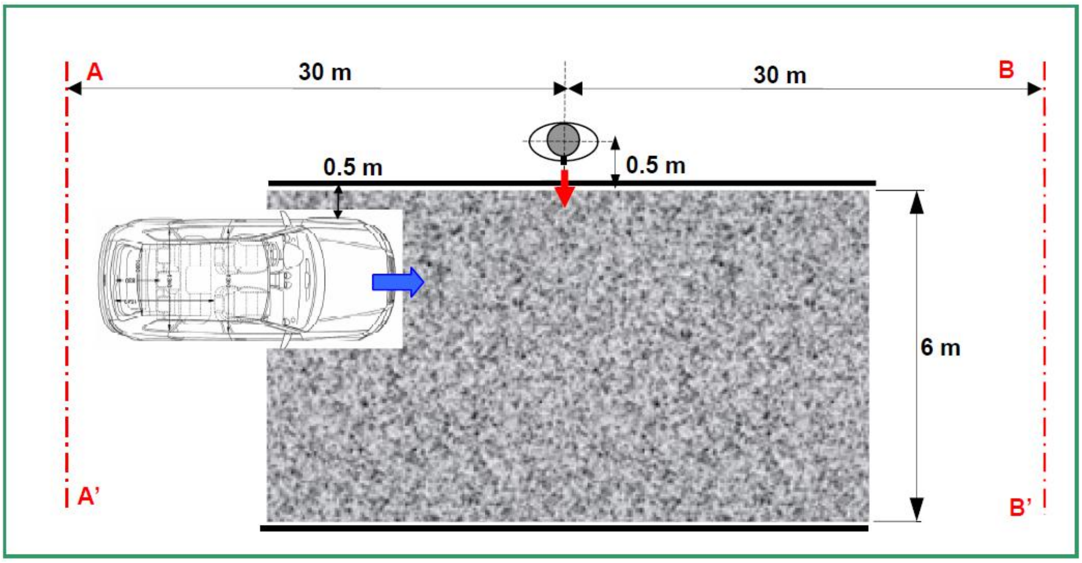

Figure 7: Waiting to cross - 1. Vehicle speed: 10, 20 and 30 km/h (setup consistent with JASIC, 2009, 1)

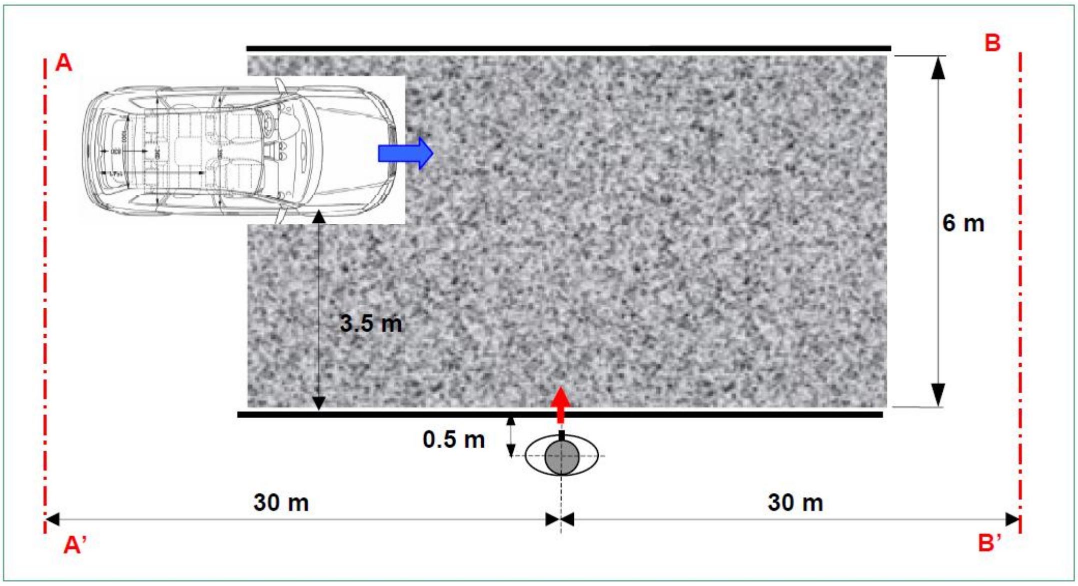

Figure 8: Waiting to cross – II. Vehicle speed: 10,20 and 30 km/h

4 Judgment protocol

In General, the content of the judgment protocol depends strongly on the type of research question, which should be answered within the listening test.

The following example of a judgment protocol is based on [1] and own experiences – for example an evaluation of the sharpness of a possible warning signal would need different questions.

- General information about the participant:

• **Gender**: o male o female
• **Age**: o child: 0-14 o young person: 15-24 o adult: 25-64 o senior: 65+
Physical restrictions • general restrictions: o visual o Ametropie o visual-impaired o blind o auditory o left ear entire, partial o right ear entire, partial o both ears entire, partial

- Have you had visual impairment all your life or is it something acquired later in life?
- What, if any, residual vision do you currently have? Does this extend to shape, colours?
- Do you wear a hearing aid?
- When crossing the road, what influences your choice of crossing location?
- What do you consider are the most significant hazards to you when crossing the road?
- How do you negotiate your way around or through a car park?
- What audio cues do you use when crossing the road?
  - What do you listen for to tell you when it is safe to cross?
- What visual cues do you use when crossing the road?
  - What do you look for to tell you when it is safe to cross?
  - Are audio or visual cues more important to you when crossing the road?
- If the participant has not always been vision-impaired: Does that influence your crossing behavior now?
  - If the audibility of quiet vehicles could be improved, what types of sound would you prefer (engine noise, reversing alarm type signal, natural sounds)?
  - If non-audible technologies were to be developed in the future which would alert you to the presence of quiet vehicles, would these be useful (e.g. vibrations through a white stick or mobile phone, etc.)?

5 References

[1] Morgan P., Morris L., TRL Report PPR525 – Assessing the perceived Safety Risk from quiet electric and hybrid Vehicles to vision-impaired Pedestrians

[2] JASIC; A study on approach warning systems for hybrid vehicle noise in motor mode; 2009

[3] NHTSA; Quieter cars and the safety of blind pedestrians: Phase I; 2010

[4] Dubois F., Renault, Acoustic Measurement of Ambient Sounds, 13.12.2011

[5] Garcia J., IDIADA, Acoustic Measurement of close to Accident Scenarios, 19.01.2012

[6] Garcia J., “eVader – Electric Vehicle Alert for Detection and Emergency Response”, Part B, 2010

[7] Bech S., Zacharov N., Perceptual Audio Evaluation, 2006

ANNEX A: Acoustic Measurement of close to Accident Scenarios (IDIADA)

1 Introduction

The objective of this protocol is to define the measurement procedure to quantify the exterior noise detected by pedestrian in closet o accident scenarios denoted as:

- Vehicle turning – I (Near)
- Vehicle turning – I (Away)
- Vehicle turning – II (Near)
- Vehicle turning – II (Away))
- Walking along & Backing vehicle (Near)
- Walking along & Backing vehicle (Away)
- Waiting to cross – I
- Waiting to cross - II

The geometric arrangement of this scenarios are presented below

2 Instrumentation set-up

Dummy Head: Head Acoustics
Acquisition system
Equalization filter: linear LIN or L0
Synchronization & sampling frequency: 48 kHz
Recording Range: 104 dB
Recording 24 bits

GPS system located on a point on the center line of the vehicle

Distance of Head to the pavement: see pictures
Hight: 1.50 m

3 Measurement conditions

Photos of the measurement arrangement
Meteorological conditions (precipitations, wing, temperature and fluctuations during the measurement period)
Connectors (preferably XLR)
Microphones: frequency response

Table 1, summarizes the minimum elemental lane width for different types or roads used for different vehicles.. From this information we have assumed an average elemental lane width of 3 m.

Table 1 Summary elemental lane widths

Assumption	Width of vehicle	Additional margins	Elemental lane
Vehicles stopped or moving < 15 km/h	1,8 m	2 × 0,2 m	2,2 m
Big passenger cars (4×4) stopped or in narrow lanes (limit 30 km/h)	2,15 m	2 × 0,2 m	2,55 m
Automóviles grandes (4×4) en vías urbanas normales (límite 50 km/h) Big passenger cars (4×4) stopped or in normal lanes (limit 50 km/h)	2,15 m	2 x 0,3 m	2,75 m
Buses and trucks in normal lanes (limit 50 km/h)	2,5 m	2 × 0,375 m	3,25 m
Roads (limit 90 km/h)			≥3,5 m

The accident scenarios selected to assess the noise detected by pedestrian in close to accident scenarios are presented below in figures 1 to 7. The relative position of the vehicle, the acoustic head and the vehicle speed are also defined in the figures.

The measurement will start when the frontal part of the vehicle is on the line A-A' and it finishes when the rear part of the vehicle reaches line B-B'

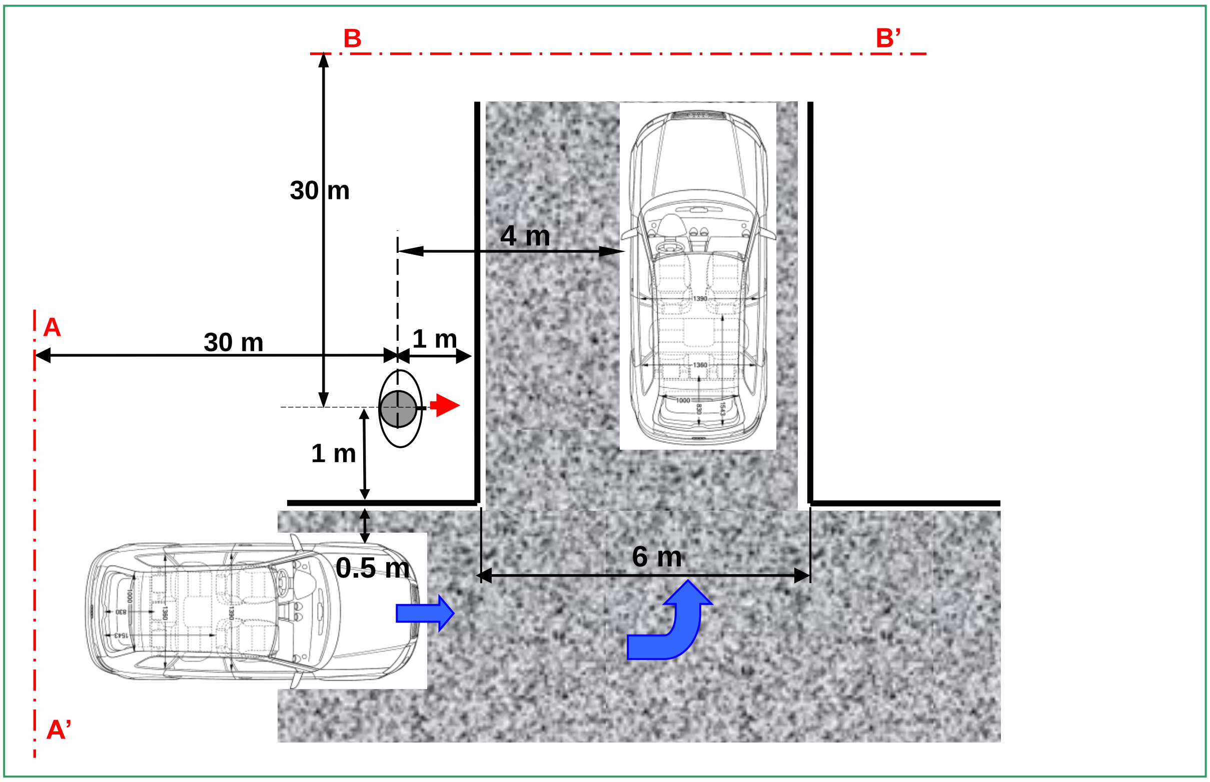

Figure 1: Vehicle turning – I (Near). Vehicle speed: 10, 20 and 30 km/h

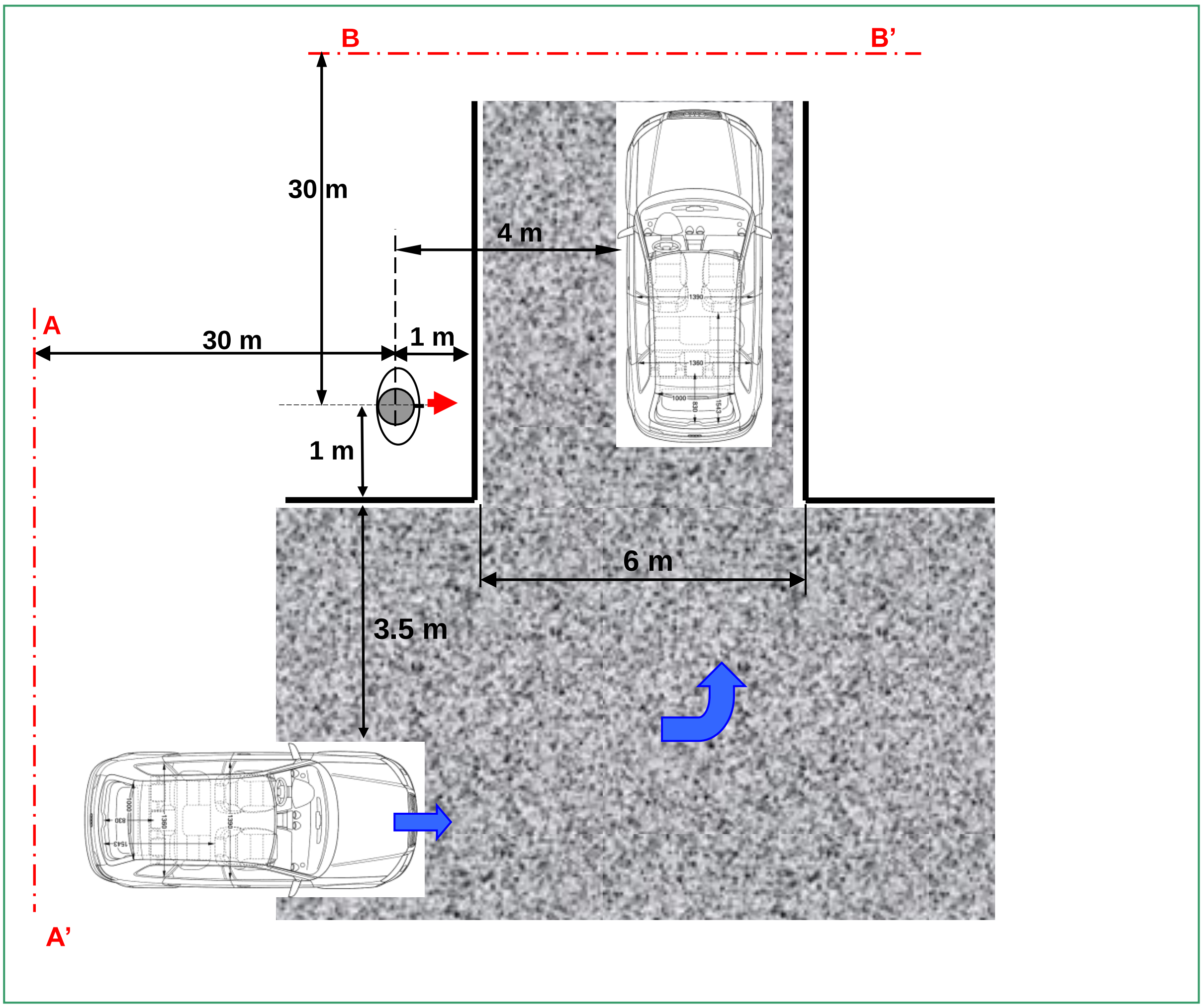

Figure 2: Vehicle turning – I (Away). Vehicle speed: 10, 20 and 30 km/h

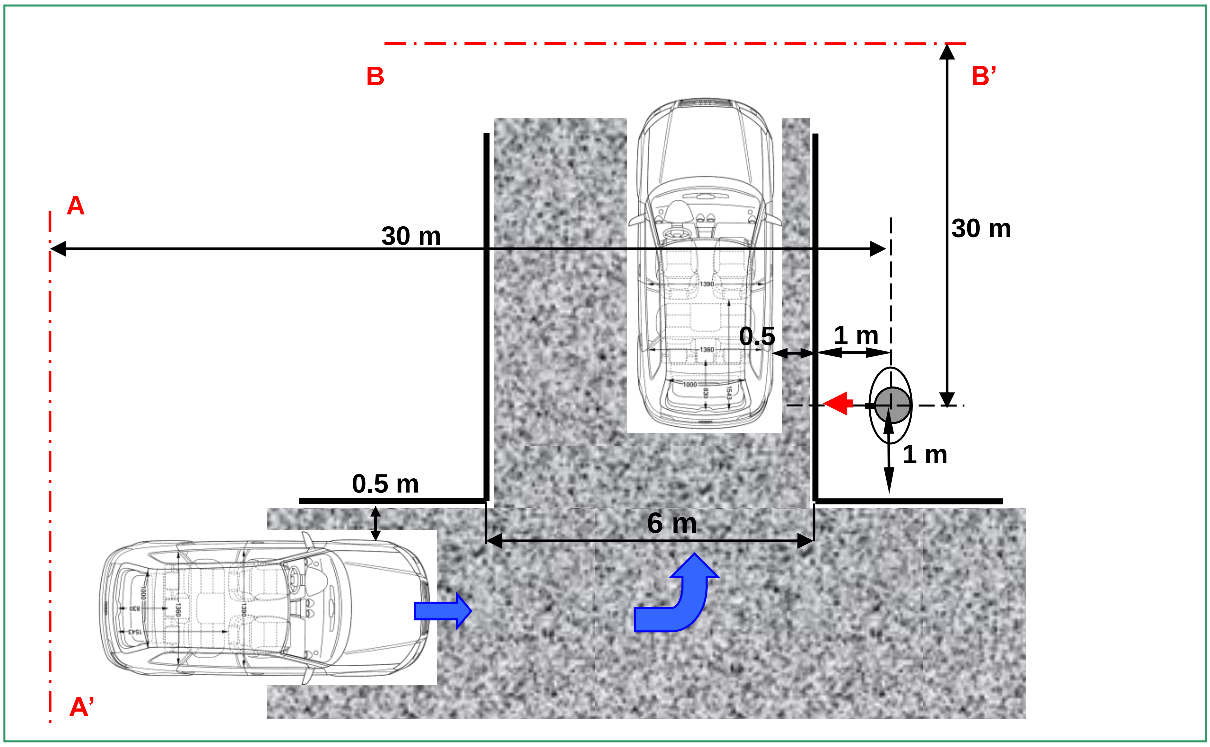

Figure 3: Vehicle turning II (Near). Vehicle speed: 10, 20 and 30 km/h

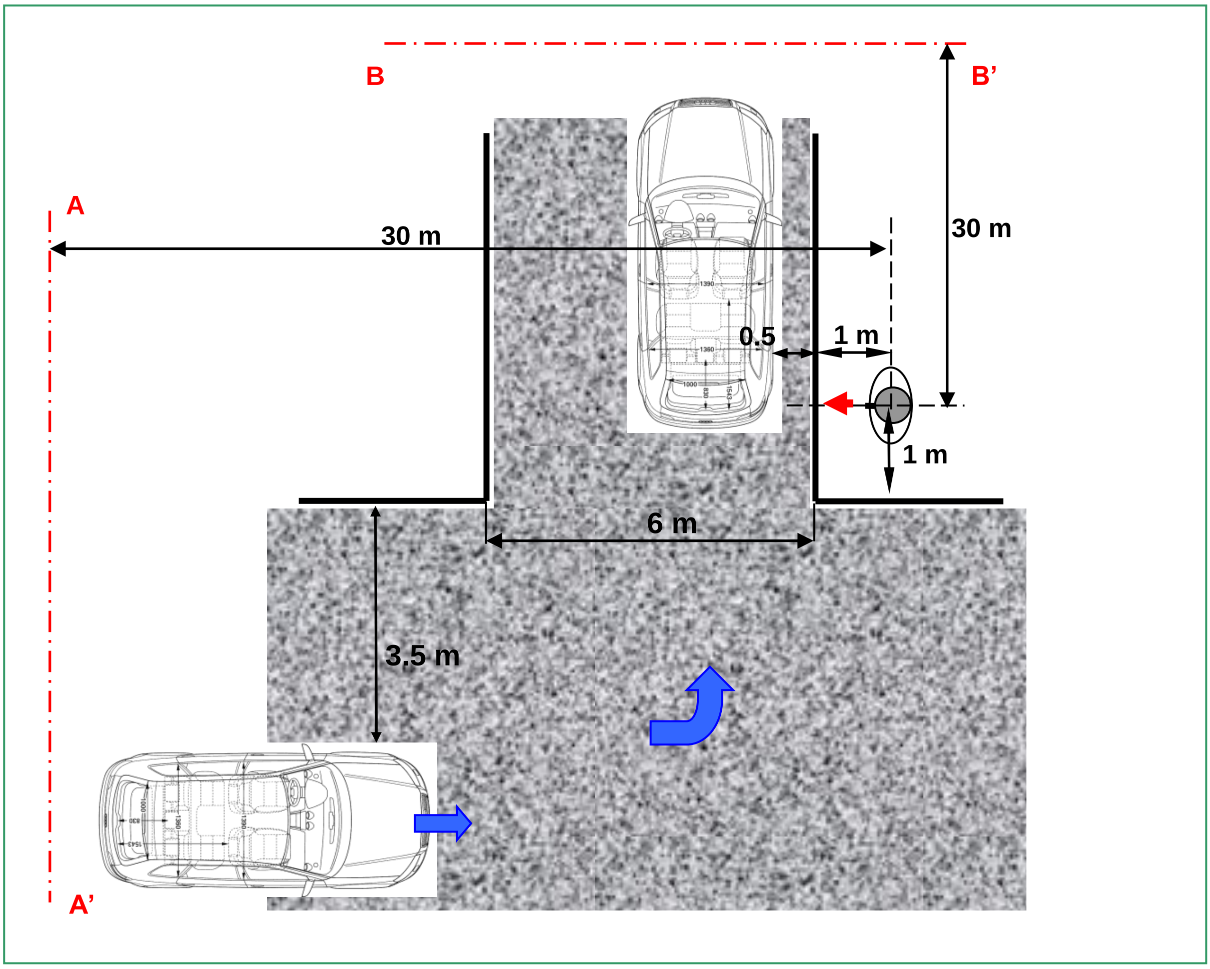

Figure 4: Vehicle turning II (Away). Vehicle speed: 10, 20 and 30 km/h

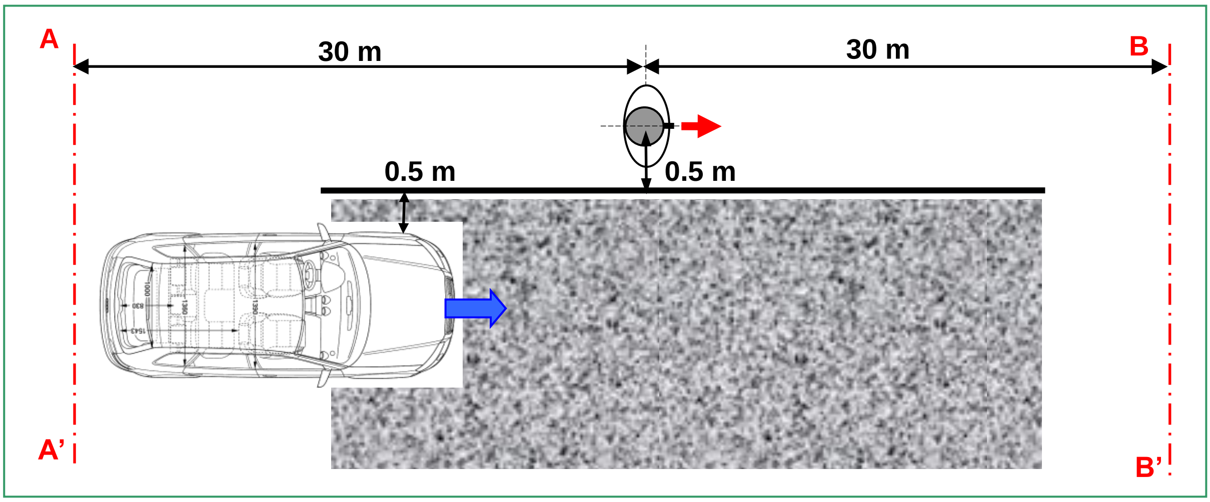

Figure 5: Walking along & Backing vehicle (Near) scenario. Vehicle speed: 10, 20 and 30 km/h (Set up consistent with JASIC, 2009,1)

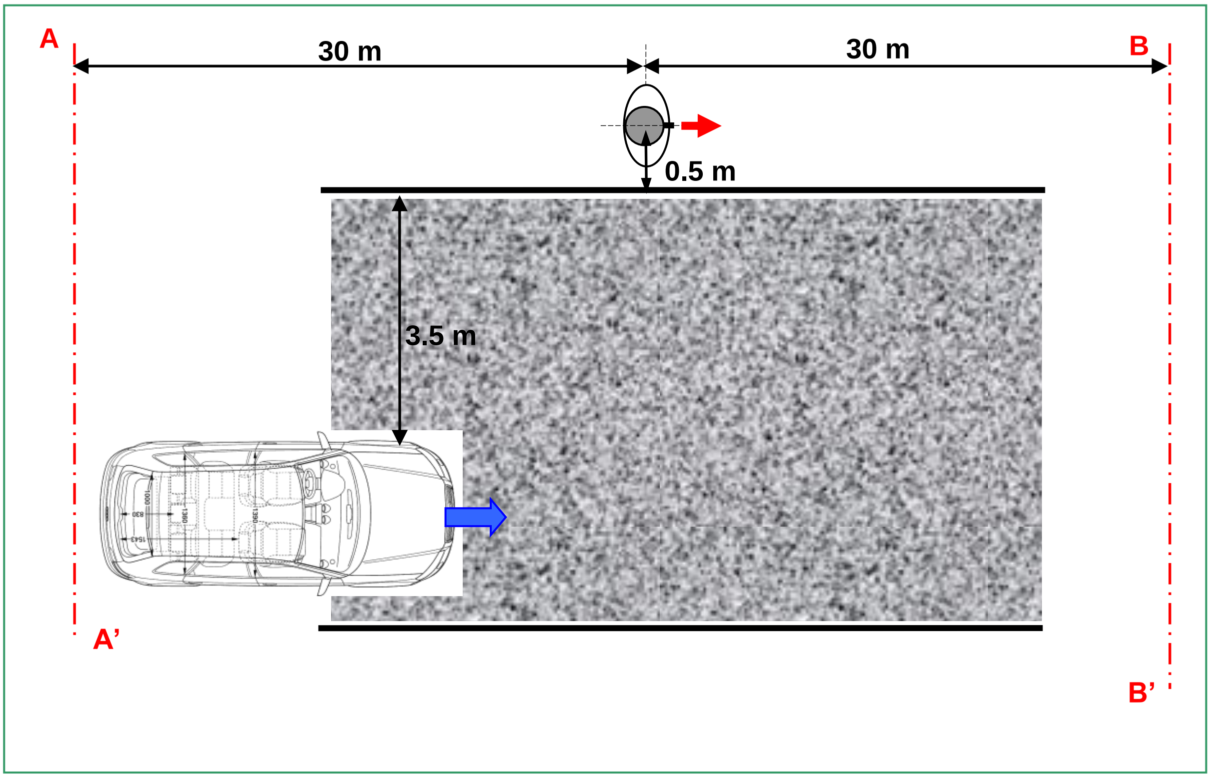

Figure 6: Walking along & Backing vehicle (Away) scenario. Vehicle speed: 10, 20 and 30 km/h (Set up consistent with JASIC, 2009,1)

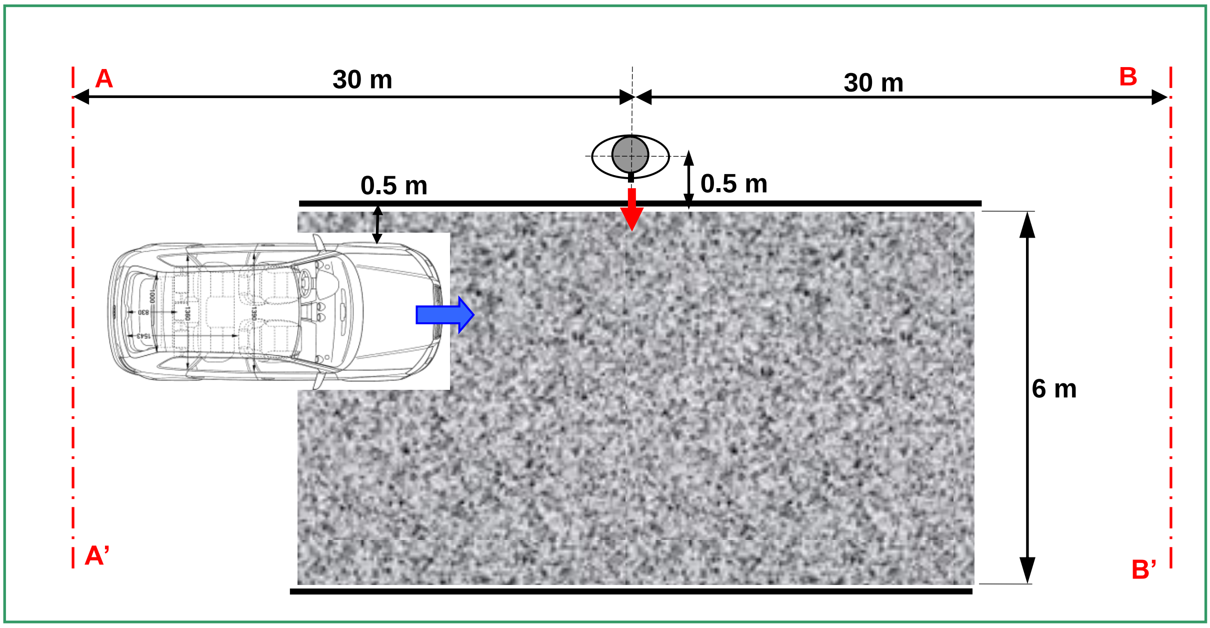

Figure 7: Waiting to cross – I. Vehicle speed: 10, 20 and 30 km/h. (Set up consistent with JASIC, 2009,1)

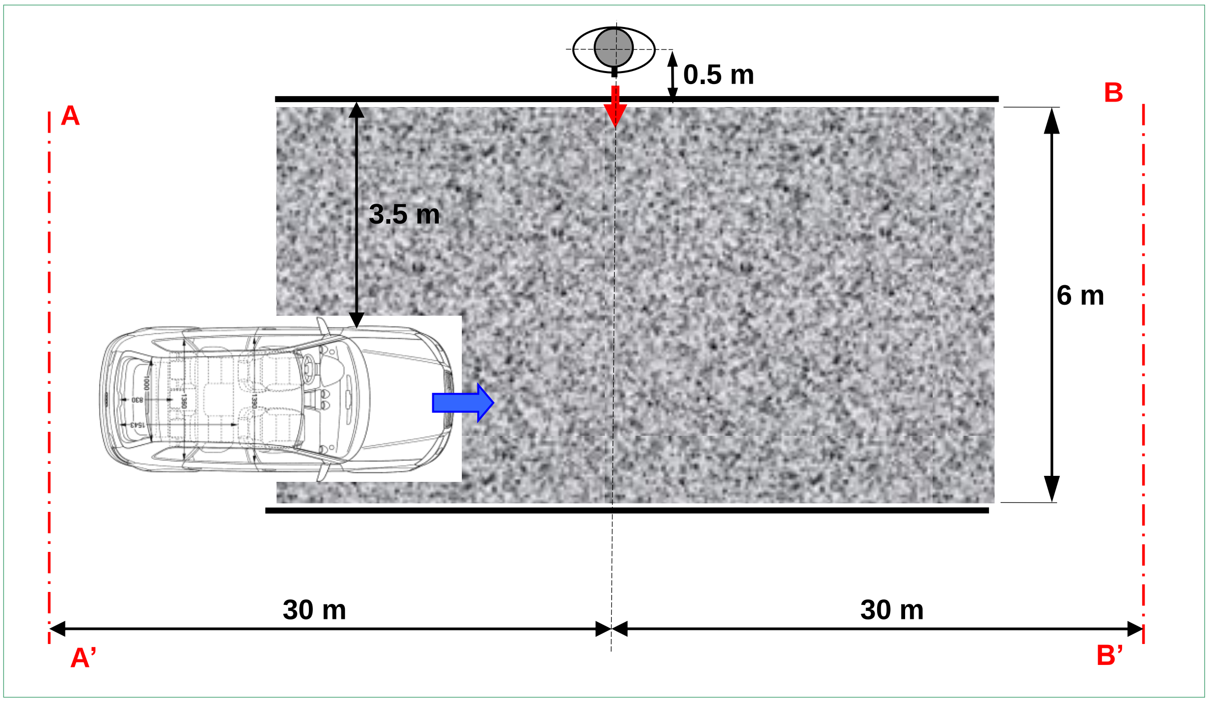

Figure 8 : Waiting to cross – II. Vehicle speed: 10, 20 and 30 km/h.

The objective of this protocol is also to be used to measure the close-to-accident position produced by IC vehicles. In this case, due to the range of vehicle speeds considered, these type of vehicles will be measured in second and third gear. For EV, the only parameter to be taken into account will be the vehicle speed.

The following matrix of results will be produced:

Scenario	Gear (for IC vehicles)	Vehicle speed (km/h)
Vehicle turning – I (Near)	2,3	10, 20, 30
Vehicle turning – I (Away)	2,3	10, 20, 30
Vehicle turning – II (Near)	2,3	10, 20, 30
Vehicle turning – II (Away)	2,3	10, 20, 30
Walking along / Backing vehicle (Near)	2,3	10, 20, 30
Walking along / Backing vehicle (Away)	2,3	10, 20, 30
Waiting to cross - I	2,3	10, 20, 30
Waiting to cross - II	2,3	10, 20, 30

Tolerance for distances: ± 5 cm
Tolerance for vehicle speed: ± 2.5 %

4 Results presentation

A-weighted levels during all the measurements period
Noise spectrum during selected period (colormap)
File format: wave.
An alternative format (.dat) will be also provided to have some redundancy for safety: Name file: YearMonthDate_City_Site_Partner

In order to have the calibration information with wav format, we have to record a calibrated sound source in a wav. File too (pistonphone at 1 kHz at X dB)