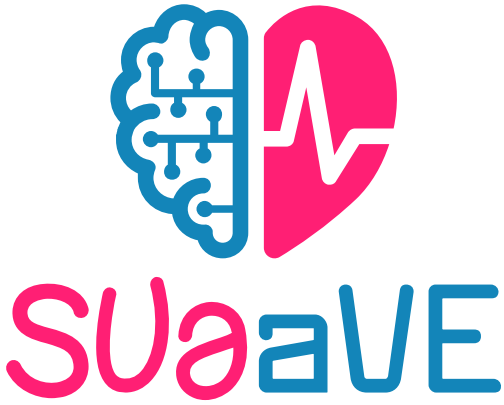

SUpporting acceptance of automated VEhicle

Deliverable 6.1. ALFRED Use cases

DELIVERABLE IDENTITY	
Work Package No.	WP6
Work Package Title	D6.1 ALFRED assessment and demonstration
Task	Task 6.1. Evaluation framework and ALFRED use cases
Date	2019/10/31
Dissemination level	**PUBLIC**
Category	**Report**
Document status	☐ Draft ☐ Ready for internal review ☒ Project Coordinator accepted

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 814999

Document control page

AUTHOR	
Participant Partners(s)	IDIADA, IBV, RUG, VEDECOM, IFSTTAR
Deliverable Leader	IDIADA
Main Author(s)	Davide Salanitri (IDIADA), James Jackson (IDIADA)
Other Author(s)	Thierry Bellet (IFSTTAR) Sofía Iranzo Egea (IBV) Berfu Unal (RUG) Ebru Dogan (VEDECOM)

Revision History

VERSION	DATE	AUTHOR	PARTNER	CHANGES MADE
V01	07/10/19	James Jackson	IDIADA	Original version
V02	14/10/19	Davide Salanitri	IDAIDA	Use case event proposals from partners and outcomes added
V03	18/10/19	James Jackson	IDIADA	Use case development process added
V04	27/10/19	James Jackson & Davide Salanitri	IDIADA	Final draft
V05	30/10/19	Sofía Iranzo Egea & Juanma Belda Lois	IBV	Internal Review
V06	30/10/19	Davide Salanitri	IDIADA	Correction after review
V100	31/10/19	N. Palomares	IBV	Approved

Legal disclaimer

Table of Contents

Terminology and Acronyms

EU	European Commission
ALFRED	Level of Automation Four+ Reliable Empathic Driver
UC	Use Case
V-HCD	Virtual Human Centre Design
ACE	Adaptive, Cognitive and Emotional Interface
ODD	Operation Design Domain
VRU	Vulnerable Road User
CAV	Connected Autonomous Vehicle
CAVE	Cave Automatic Virtual Environment
HMD	Head Mounted Display

Table of Figures

Table of Tables

EXECUTIVE SUMMARY

This deliverable is related to task 6.1 of the SUaaVE project. It is a “living document”, which is to say that it will continue to be update throughout the first phase of the project. The principle aim of the deliverable is to define the use cases which join to form the project’s framework for evaluation. These use cases have been identified and shaped around the input of all project partners – but primarily those responsible for the models which are being defined within the project. Each of these partners has had input based upon the initial work carried out and the current information base upon testing needs. The use cases defined within this document outline the evaluation framework in its current state, however these are intended to be flexible with changes possible dependant on demands as they stand as the project progresses.

1. INTRODUCTION

1.1. What is a vehicle use case

1.1.1. Generic definition of use case

A key part of the development of any product or service involves careful thought of how it will be used once in production and released into the real world. Within the field of Human Factors, this process closely considers the needs of the end user and their points of interaction (Wilson and Sharples, 2015). This methodology provides a mean by which design and development can take into account real scenarios under which something might be used by creating solutions that are relevant to end users. Similarly, it provides a mean for post development evaluation which has applicability and allows for continued reflexion of whether the product or service is applicable to its specific end use (Vermeeren et al., 2010).

The principal methodology for this process involves the definition of use cases. Use cases define generic and/or specific scenarios under which a product or service eventually be used. They are often comprised of a series of steps which define typical events based around interactions between a user and a system Möller (2014). Typically use cases specify a scenario within which the product or system is intended to function. They will often take the form of 'stories' describing the events involved in use and include information with regards to any specific points of user interaction. A wide variety of additional details can also be considered, including aspects such as specification of the users' involved, the scope of operation, and the conditions under which something might eventually be used (Wachenfeld et al., 2016).

1.1.2. Transportation use case (user journeys)

Use cases are widely used within the development of transportation systems to envisage the eventual use of products and systems. Within the domain of transport and mobility design the product or system is intended to provide a means of travel between an origin and destination and a key part of this is can be viewed as user journeys. They are key to the understanding of how users complete trips and act as umbrella under which a wide variety of different components can be defined and specified (Wachenfeld et al., 2016).

As mentioned, transportation use cases can take the form of user journeys defining a wide range of components. Principally, this involves contextual details of a use scenario, which will include the general steps involved in travelling between an origin and destination. At a higher level of complexity, use cases can also define more specific conditions that might occur within the use of such a product or system. This involves detailed definitions of how the scenario affects the user, and how they might respond (Example in Figure 1).

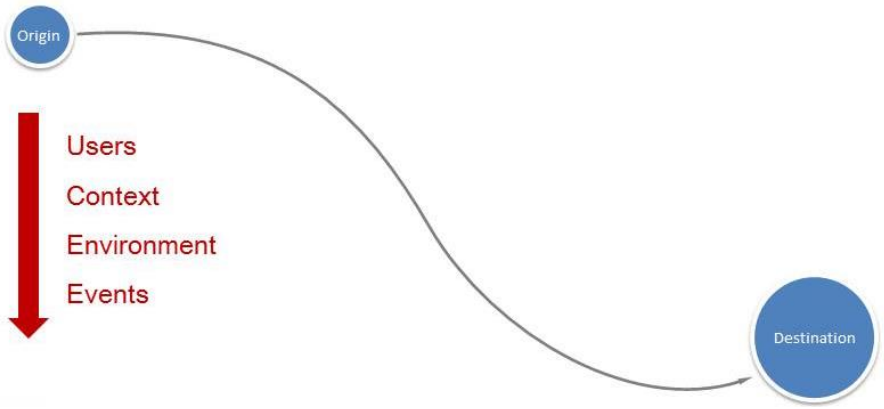

Figure 1 Journey use case from origin to destination

In vehicle development particularly, use cases are widely applied to provide foresight into how the end-product might be used once it is operating within the real world (example in Figure 2). As with transportation in general, this takes the form of journeys involving use of the vehicle as a means of travel by users. Likewise, in addition to defining the high-level use of vehicles in terms of a vehicle journey use cases can be also used to refer to more specific scenarios which take place with the vehicles use. The more specific use cases define particular events which might be expected to take place during the use of a vehicle. These can form part of more general definitions of how the vehicle is used (journeys) but can also focus on eventualities outside of normal use (exceptional).

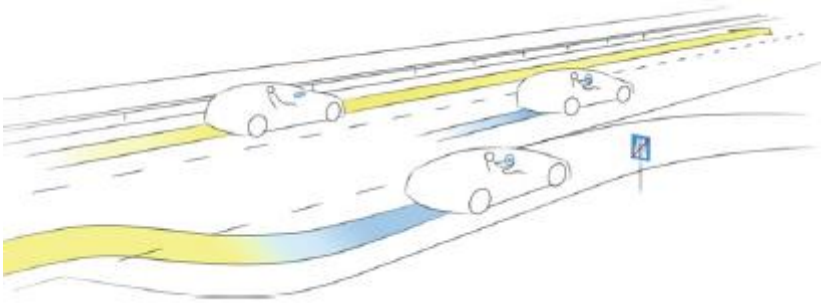

Figure 2 Vehicle leaving a highway – a short scenario based use case

1.2. The SUaaVE Project and the ALFRED Concept

1.2.1. The SUaaVE Project

The SUaaVE project sets out to develop and evaluate systems which are for use within a level 4 autonomous vehicle intended for market entry after 2030 and revolves around the development of a system concept known as ALFRED. As with any level 4 vehicle, the concept will function inside of a defined operational domain, within which it will always be controlled autonomously during normal conditions. The parameters of vehicle use do not extend to use outside of this domain and, as such, it will only be used by passengers, with no possibility of

the vehicle being driven. Within this operational domain the vehicle will therefore function as a fully autonomous vehicle, needing to manage all normal scenarios without relying on a human user.

1.2.2. The ALFRED Concept

The ALFRED concept is intended to intelligently respond to users by means of a series of models, whose development forms a key part of the SUaaVE project. These models set out to take a series of user-based components into account, with the intention of adapting the system in a way that will improve vehicle behaviour across a number of different functions, and control communication to and control by the user. The ALFRED concept will control these varied components dictated by the output a series of models, considering user acceptance, ethics, emotions, and comfort. Whilst the system is focused around the vehicle occupants, it also considers other users of the transport systems that may interact with the ALFRED vehicle – pedestrians, cyclists, passengers of other vehicles, and drivers of other non-autonomous vehicles amongst others.

In addition to the development of this empathetic model, the SUaaVE project sets out to define other components of the vehicle system. This involves the creation of an interface for interaction with users, known as ACE. This interface will be the end model for the vehicle's dynamic behaviour.

1.2.3. Use Cases for SUaaVE

Like previously stated, use cases can be applied in the development of many different types of products and systems. Within the SUaaVE project use cases have been defined as an important component in the development and evaluation of ALFRED. The primary objective of use cases within the SUaaVE project is to provide the basis of a framework for evaluation of the developed empathetic model, however, by extension this also involves its outputs including testing influence of changes in vehicle functions, the effect of the ACE interface, and the behaviour of the vehicles dynamic model.

1.2.4. SUaaVE Virtual Platforms

In addition to the development of the ALFRED vehicle and its associated components, the SUaaVE project aims to develop and utilise a series of simulated virtual test environments. These will be used during both the research and development stages, and the evaluation phase during the project. The primary platform developed for simulation is known as the Virtual Human Centred Design platform (V-HCD), which provides virtual environments adaptable to a variety of different methodologies. Part of the V-HCD development will involve the creation of specified scenarios that can be used throughout the project phases. Supplementing this will be a series of other virtual platforms which will be utilised depending on demands, which like the V-HCD, will involve the creation of simulated test scenarios. The defined use cases are intended as a common source for the specification of virtual scenarios for the V-HCD, and across any other simulation platforms used in the project.

1.3. Use cases as part of ALFRED development

Throughout development of the ALFRED system, in some studies it may be necessary to offer relevant scenarios to its eventual use, within which scenarios for research and formative testing can take place. In terms of research studies conducted, this will involve investigation around components of acceptance, ethics, emotions, and comfort.

At this investigative stage, use cases will mainly be used in scientific investigation, conducted under experimental conditions. Consequently, use cases must offer controlled scenarios with defined variables, whilst maintaining the context of eventual use.

Considering these requirements under which use cases will be applied, during the research phases, it is likely that they will comprise of short scenarios. These will look to elicit a single user response dependant on minimal independent variables, which can then be measured. For this, each of the use cases must offer definitions for users, context of use, the environment, and events.

2. USE CASE DEFINITION PROCESS

2.1. Definition of the operational domain

The specification of use cases will follow some general guidelines set out by the definition of an operation design domain (ODD). An ODD is key to the design of an L4 vehicle, because of the fundamental role it plays in specifying the conditions under which the vehicle will be able to function under full autonomy. This entity acts as the source for much of what is defined within the use case. Whilst at this stage there is no specific definition of the ODD, it is a source of consideration for several aspects – specifically with regards to the context of use for a vehicle, and the environment within which it operates.

The ODD will act as a source of context for the use cases and provide real-world relevance. Its content is particularly important when considering the models for comfort and emotions, as it follows the limitations of what might be considered for each model, in which they act as external factors. It also has an important part to play when considering the extremities of operation, and therefore when in the definition of use cases in which the vehicle may be unable to continue driving.

The proposed components of the ODD for the SUaaVE are as follows (this is a non-exhaustive list and may progress as the project moves forward).

- Rules for the physical boundaries where vehicle is able to operate (on what roads can it travel).
- Rules for vehicle journeys (level of user control, pick-up and drop-off locations and route override).
- Rules for operational conditions (weather and lighting conditions).

Rules/norms for interaction with other road users (external) – common method of communication between autonomous vehicles and other road users, within the operational domain.

2.2. Definition process for use cases

The model for the definition process of the use cases is depicted in the image below.

The first step in the definition of the use cases process is the definition of external factors, which is the definition of the factor affecting ALFRED's operation and its occupants (Figure 3).

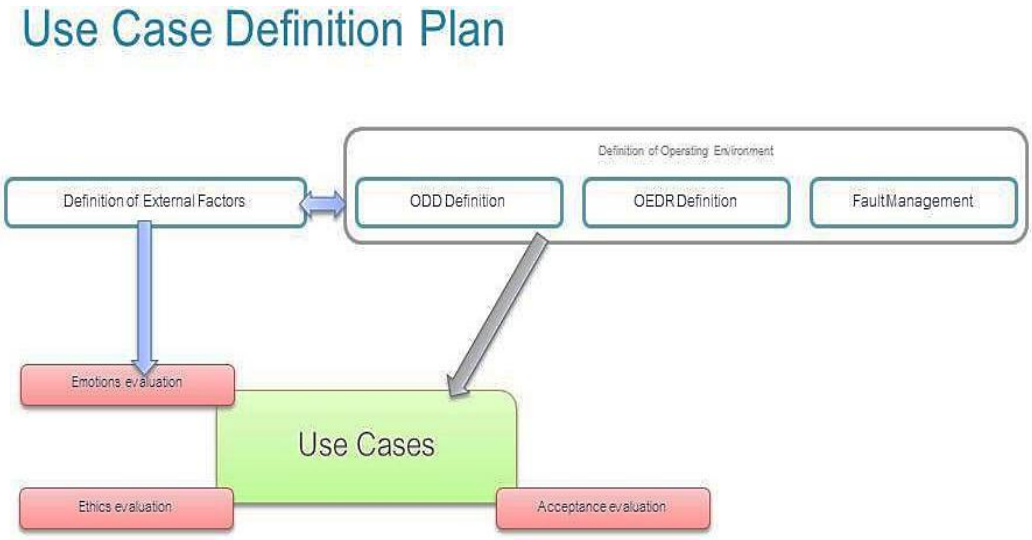

Figure 3 Definition process of the use cases

The external factors are principally used for the development of the emotional model. The definition of the external factors takes place in parallel to the development of the ODD and all the identified factors are possible within the operating environment. The external factors can be grouped by:

- **Variable environmental factors**. For example: route, operational zones, lane width, lane boundaries, path obstacles, visual obstacles, location type, location appearance, time.
- **Fixed environmental factors.** For example: visibility, light levels, temperature, weather type, traffic conditions.
- **Variable vehicle operation factors.** For example: speed, dynamic behaviour, selected route, climate settings, visual settings, entertainment.
- **Fixed vehicle operation factors.** For example: dynamic characteristics, exterior visibility, comfort level, colour, appearance.
- **Situational user factors (Variable).** For example: journey purpose, pre-journey activity, post-journey activity.
- **Profile user factors (Fixed).** For example: personality characteristics, preferences, past experiences, physical capability and characteristics, cognitive capability and characteristics.

2.3. Users

Regarding the type of users who will interact with ALFRED, they were divided into two groups: primary and secondary.

The primary users are the ones directly interacting with the vehicle. These are the users inside ALFRED when the vehicle is functioning. The primary users were divided for demographic characteristics (old vs young vs adults) for number of users (single user vs group of users) for mobility (user needing accessibility vs user not needing accessibility) and by user characteristics and emotional state.

The secondary users are users not directly interacting with ALFRED, such as Virtual Road Users (VRUs), other vehicles drivers, service users and transport management personnel. Also for the secondary users, they will be divided by demographic groups and mobility.

2.3.1. Context

The journey context is necessary to cover multiple types of situations. The journey context characteristics are:

- The start and finish location: that is where the scenario starts and ends.
- The journey stop(s): another thing to be considered is one or various stops during the scenarios. These stops were implemented for a contextual reason, for example to pick up another passenger or to stop on another location before reaching the final destination. They were also implemented for a technical reason, which is to reduce the continuous exposure to a virtual environment, which could increase the probability of experiencing adverse symptoms (i.e. cybersickness).
- Purpose of the journey: to contextualise the scenario, a purpose of the journey has to be defined. The purpose of the journey influences all the aspect of the context, such as the start and finish destination, the stops and the user activities in the vehicle.
- User activity before/after the journey: the activities the users carry out before and after the journey are important for the context as they influence the journey start, stop and finish and they influence the user state of mind.
- Using activity during journey: the activities carried out during the journey are included in the context as they affect the emotions, acceptance and trust of the users toward the vehicle. The activity will depend on the type of users and the journey context in general.

2.3.2. Environment

The environment or operational environment is the field where Alfred will operate. The interaction between the vehicle and the environment will affects the user experience, emotion, acceptance, trust and comfort. During the scenarios, ALFRED will respond to change in the operational environment and this will trigger different perception by the users. In details, the operational environment is composed by:

- The physical ODD zones: that is where ALFRED can function and/or it is allowed to travel. For a definition of ODD refer to section 1.5.
- Domain rules and norms: refer to regulations and the general behaviour patterns within the operational environment. This can include traffic laws and regulations applicable to where the vehicle is operating, but also includes other rules that users of the environment are bound by (i.e. pedestrian crossing rules, driving on the right / left of the road, and speed limits). Norms consider the accepted actions of traffic and other users within the domain (i.e. general levels of driver aggression, and the means of communication between users)
- Weather: the weather during the scenario will strongly affect the user experience. More in details, the change in weather can affect the sense of acceptance, safety and trust on the system, the vehicle dynamic (comfort) and the interior comfort (such as different light).
- Infrastructure: the infrastructure will be a part of the external environment. Road infrastructure can influence the journey path, characteristic and domain. As an example, a roundabout, a speedbump or a toll gate could influence the vehicle dynamics, the user comfort and acceptance of the vehicle.
- Road condition: also the road conditions are an important part of the environment as they can affect the journey.

2.3.3. Events

The events happening during the scenario have been developed in order to trigger controlled reaction to the user emotional state and perception. More in depth, the events are used to investigate the reaction that the users have to certain situations. There are two types of events, generic and specific.

Generic events: generic events refer to the type of situations that are usual and often occur during a normal journey. They will be comparable between use cases. They can refer to:

- Infrastructure use.
- Road user behaviour and interaction: such as behaviour of VRUs crossing the street or interacting with the vehicle environment.
- Journey start and finish: this refers to every event which happens or can affect the start and finish location.
- Journey planning: there will be events in the scenario which change or influence the journey planning, such as deviation to pick up other passengers.
- Operational domain.
- User desires/choices: these types of events are decisions that the user can make following an input from the vehicle. As an example, a change of ride setting or change in interior temperature.

Specific events will be events that do not usually occur in a normal journey and are proposed to trigger change in the user status (emotional, psychological and physical). The specific events will be included in shorter scenarios and will not be comparable among use cases. The specific events include

- Environmental changes: changes in the environment that are not foreseen, such as change in weather conditions or stand still queues.
- Infrastructure exceptional events: refers to sudden and unexpected changes in the infrastructure. For example, road works.
- Road user exceptional events: unexpected behaviour by other users such as traffic rule breaking.
- Exceptional use desires/choices.

The specific events can also be divided in events happening inside the ODD or outside the ODD. More specifically:

Outside of ODD:

- System failure (i.e. car breakdown).
- Emergency situation management (i.e. accident involving other vehicles).
- Safe stop procedures.
- Forbidden actions by ALFRED occupants.
- Environmental extreme conditions.
- Procedure when leaving ODD zone.

Inside of ODD:

- Intersection events.
- Traffic scenarios (i.e. stand still queue).
- User agreement procedures.

2.4. Distinction between use case types

As previously stated, there is a demand for different types of use cases dependant on specific application. Within SUaaVE, use cases are to be applied across multiple investigative and developmental phases, with distinct applications depending on stage and methodology. Use cases must provide relevant scenarios to provide context, but must also be able to encompass all possible situations needing to be considered.

To meet all of the demands for investigation, development, evaluation, and demonstration, a system of categorisation for use cases have been defined from the outset.

2.4.1. Trip use cases

Trip use cases encompass user journeys and define scenarios from a standpoint of generalised use. Following the process set out above, they comprise of a definition of specific users, a context for use, and a defined environment. Underneath this, are set out a series of individual events which take the form of a long scenario. The events defined under a trip use case are applicable to the scenario context and specify general occurrences.

These longer use cases can be used when carrying out assessment regarding the whole system. This is done by presenting a real-world applicable scenario. Trip use cases are focused around passengers acting as primary users of the ALFRED vehicle within the context of a journey from origin to destination. There is, however, the potential for a similar concept to be applied to other transportation system users; i.e. a use case dedicated to a pedestrian or other VRU, or a use case dedicated to a driver of another non autonomous vehicle.

2.4.2. Situational use cases

Situational use cases provide the tightly defined and controllable scenarios required by scientific investigation, and provide the means for specific demonstration and evaluation. Like the longer trip scenarios, they include defined users, specified context, and information regarding the environment. The sequence of events within them defines more specific occurrences, although these still join to form a scenario although with more detail. Situational events within the use case framework fall under two main categories:

1. General Events

General events are taken directly from the scenario defined within the trip use cases. These are applied within all the longer journey scenarios, although the exact sequence is dependent on the specific use case. They define normal occurrences within the use of the ALFRED vehicle which, although intended to provoke a user response, will always be regarded as common happenings.

2. Exceptional Events

Exceptional events define scenarios that can be regarded as falling outside of normal operation. These might involve clear discretions by other transport users, or could involve situations in which the vehicle leaves its functional domain or encounters an error in its operation. Being situational use cases, exceptional events always from short scenarios which are applicable for specific experimentation or for demonstration and evaluation of special operating conditions for the ALFRED concept.

2.5. Representation of SUaaVE components within definition

The definition of use cases was a collaborative effort to provide a suitable platform for all activities around the ALFRED concept. Because of this, the process has involved input from partners with regards to their individual demands of the use cases (Described in section 3). This process considered all work package leaders of the relevant models (emotions, comfort, acceptance, and ethics), the development of the ACE interface and dynamic model, and the simulation platform(s).

Work with partners responsible for the components of the ALFRED vehicle is intended to ensure that the use cases where defined in such a way that they offer relevant scenarios to assess and evaluate.

2.6. Scoping of use cases

An outline of the proposed use case development process was presented to all, with this followed by a collaborative definition of three trip-based use cases and followed with a situational use case definition. The collaborative process was employed to meet the requirement to consider the individual demands of each stakeholder. The work to specify of trip use cases followed the general process defined in the previous section. This involved the definition of primary and any secondary users within the use cases, followed by setting out the context under which their journey (and subsequent interaction) takes place, with environmental conditions then being specified.

Following this first stage of definition, partners responsible for the models forming the ALFRED concept were asked to feedback with a series of events that would be relevant to each. This involved the proposition of both general events, providing the basis for trip use cases and situational use cases, and exceptional events, which are to form an additional series of situational use cases. Other partners responsible for other parts of the development of ALFRED were also asked to put forward any events that might be relevant to the creation and testing of their contributions.

Following this feedback, a process of refinement took place, where suggestions were reviewed and combined by IDIADA to create a manageable set of events which could contribute to the definition of the eventual use cases. This combination process aimed to include all inputs made by other partners to meet all their individual demands. Use cases were then presented to all partners followed by another collaborative session working to ensure that use cases were optimised.

At this stage, initial input of partners has been considered. As the project progresses the use cases definitions are open to change in response to input from project partners with the intention that this will provide a set of use cases that is geared towards individual demands. This will follow a continued process of collaborative development and adaption of the use case definitions.

3. DEFINITION OF USE CASES

3.1. Feedback / input from model use cases

In order to evaluate all the attributes of the project framework, the group of events chosen must be able to encompass all the range of effects that want to be investigated (i.e. acceptance, trust, safety, ethics, emotion, comfort). In order to do this, input from the partners were required. Each partner developed a series of events which was able to provoke the expected response. In this section, the input from all the partners will be presented.

The events, divided by the proposing partner and the characteristic evaluated are described in Annex I.

3.1.1. Acceptance

Table 1 List of events meant to evaluate acceptance.

Events
Interaction with a group of children crossing the street
Interaction with a cyclist
Interaction with a handicapped pedestrian
Complex traffic environment (e.g. city traffic, high traffic density, interactions with other road users) versus Simple traffic environment (e.g. rural area, no interaction with other road users, low density)
Vehicle needs fuel which is visible from the dashboard
Approaching to traffic lights
Busy intersection
Stopping to get other passengers
The vehicle sends a warning signal that needs attention
Window cleaners are not working
The user watching youtube videos
Another vehicle engaging in faulty overtaking
A parked car jumping on the road
Road ahead is blocked/road is getting narrow due to road construction
Other passengers being too loud and annoying
The vehicle suddenly breaks although there seems to be nothing happening
Cyclist cut-in / Motorcycle cut-in
Zebra crossing with an emergency braking because of a pedestrian (crossing, showing the intention to cross), a traffic lights yellow/red… a VRU crossing with yellow/red
Pedestrian encounter with no zebra crossing: a situation in which a pedestrian crosses the road with an unprescribed behaviour
Intersection with no yield or stop signs with an encounter with a VRU (also animals)
Toll payment stop in a highway: call for action for the driver or passenger

Traffic jam where an aggressive driving could solve the driving criticalities (wrong way overtaking or aggressive driving… frustration of the driver in the perception of the autonomous feature inability to face with those situations).
Other car aggressive driving during a traffic jam: same above scenario from a passive perspective
Ambulance encounter: How does the human-autonomous system react to an ambulance encounter in an emergency situation?

3.1.2. Ethics

Table 2 List of events meant to evaluate ethics

Events
The vehicle is approaching an entry of a highway and increases the speed slightly above the speed limit in order to integrate safely in the ongoing traffic on highway.
A motorbike is approaching the AV on the same lane from behind. The AV drives slightly beyond the lane line in order to give safe space to the motorbike

3.1.3. Emotions

Table 3 List of events meant to evaluate emotions.

Events
Vehicle dynamics: customizable Smooth VS aggressive driving (speed, safety envelope, distance to other vehicles, accelerations and braking, etc.)
Area with traffic lights customizable. To create scenarios with fluent driving VS slow driving to trigger emotions.
A traffic jam
Rain/Fog. To create scenarios with low visibility VS sunny day
Other driver commits an infringement that affects the passenger drive (feeling angry)
Other driver commits an infringement that affects the passenger safety perception
Pedestrian approaching to a crossing zebra. (but CAV can pass before) CAV stops VS CAV does not stop
Breakdown
Accident (to finish suddenly/ Windshield broken / turned over)
Alternative route if passenger chose it

3.1.4. Comfort (Dynamic, ambient)

Table 4 List of events meant to evaluate comfort.

Events
Start
Speedbump
Passenger pick up
Car blocking (Low speed double lane change)
90deg corners
Roundabout
Country Road Section
Mid Speed Obstacle Avoidance
Hard braking
Deterministic input
Highway entry
Toll gate
Highway Lane Chge
Highway exit
Sunshine inside the vehicle (ALFRED asks to raise the sunblind)
ALFRED asks for preferred sitting position based on activity

3.2. General Events

In order to have a lesser number of events and being able to implement them all in the use cases, the events described in section 3.1.1 to 3.1.4 were combined. The combination tried to compress the number of events, but also to maintain the requested characteristics of the partners. The general events are gathered in Table 5. This section will provide details and an explanation of each event scenario.

1. **Approaching traffic lights they turn orange, the vehicle stops**: the vehicle will approach an orange traffic light with enough time to proceed before it turns red. However, the vehicle decides to stop. This event was proposed in order to evaluate the perceived safety, acceptance and trust of the user. Moreover, it can give a sense of satisfaction when seeing that the vehicle obeys the traffic rules.

2. **Approaching a zebra crossing, a disabled person is approaching, the vehicle stops:** this event is related to the previous one. This time the vehicle will stop to let a disabled person cross the street, even though it had enough time to proceed without stopping. The same reasons as the previous event underlie this one. However, this event adds an external person, which could influence the ethic and emotion field.

3. **Approaching a zebra crossing, a group of children is approaching, the vehicle proceeds:** This event is very similar to event 1 and 2, but this time instead of stopping, the vehicle

decides to proceed. The event is proposed to provoke a sense of fear for safety and anger and affects the perception of acceptance, trust and acceptability of the system.

4. **Another driver cut in front of the vehicle. The vehicle breaks suddenly:** this event includes another vehicle not abiding the traffic rule and forcing the vehicle to perform and emergency break. This event is supposed to provoke a sense of fear for safety and anger toward the other vehicle. The event will affect the sense of trust, acceptability and safety of the user.

5. **The user can select between sport (aggressive) and comfort (smooth) driving during a motorway trip. (Changes in car settings, includes lane change and overtaking):** This event includes an interaction with the user, who can choose between two different driving styles. One called "sport" that is more aggressive and includes more risky behaviours by the car such as aggressive overtaking and sudden change of speed. The other is a smoother driving style, more focused on comfort. This includes constant speed, even lower than the speed limit and overtaking only in few cases. This event will influence the sense of safety, acceptability and trust and it will affect the user comfort and satisfaction. In case of aggressive style, it can also provoke a fear for safety.

6. **The vehicle chose a different route from highway to normal way to pick up an extra passenger**: this event is a decision taken by the vehicle which will affect the stress of the user, the comfort (especially spatial) and the acceptability of the vehicle. In this event the vehicle will decide to make a detour to pick up another unknown passenger. This event will only occur in use case 1.

7. **The vehicle overtakes a cyclist cutting in front of the vehicle on a double lane road:** this event includes the vehicle overtaking a cyclist cutting in front of the vehicle on a double lane road. The event is supposed to provoke anger toward the cyclist and satisfaction for the vehicle manoeuvre. Moreover, it is supposed to influence the sense of safety, acceptability and trust.

8. **The vehicle overtakes a cyclist cutting in front of the vehicle on a single lane road:** this event is similar to event 7, with the exception that it happens on a single lane road, where it is more risky and difficult to overtake a cyclist. In this case the event will provoke a strong sense of fear for safety and anger. The event will also influence the sense of trust, safety and acceptability.

9. Speedbump

10. 90 degrees turn

11. Roundabout

12. Red traffic light

13. Green traffic light

14. Toll gate

These events are normal road situations which propose to affects mainly the user comfort, especially the dynamic comfort. These events can also provoke a sense of satisfaction (green light) and affects trust, acceptability and safety when rules are abided (red light).

15. Sunlight inside the vehicle (the vehicle asks to raise the sunblind): this event will include and interaction with the user. At the start of the drive, the sunlight will go through the vehicle, potentially affecting the user visual comfort. The vehicle will ask the users if they want to raise the sunblind. The event will also give a sense of relief and satisfaction to the user.

16. The vehicle asks for preferred sitting position based on activity: As for event 15, also event 16 includes a decision by the user. The vehicle will ask the user to change sitting position depending on the activity the users are performing. This event is supposed to influence the perceived comfort (especially postural) and give a sense of relief and satisfaction.

Table 5 General events and the responses they are meant to evaluate.

Generic Events	Trust	Safety	Acceptability	Environmental sustainability	Comfort and convenience	Fear (Safety)	Fear (Stress)	Distress	Anger	Relief	Satisfaction	Spatial	Thermal	Acoustic	Visual	Tactile	Postural	Hygienic	Dynamic
1. Approaching traffic lights they turn orange, the vehicle stops	X	X	X								X								
2. Approaching a zebra crossing, a disabled person is approaching, the vehicle stops	X	X	X								X								
3. Approaching a zebra crossing, a group of children is approaching, the vehicle proceeds	X	X	X			X	X		X										
4. Another driver cut in front of the vehicle. The vehicle breaks suddenly.	X	X	X			X			X										X
5. The user can select between sport and comfort driving during a motorway trip.	X		X		X	X					X								X
6. The vehicle chose a different route from highway to normal way to pick up an extra passenger.				X	X		X				X	X							
7. The vehicle overtakes a cyclist cutting in front of the vehicle on a double lane road	X	X	X					X	X		X								X

Generic Events	Trust	Safety	Acceptability	Environmental sustainability	Comfort and convenience	Fear (Safety)	Fear (Stress)	Distress	Anger	Relief	Satisfaction	Spatial	Thermal	Acoustic	Visual	Tactile	Postural	Hygienic	Dynamic
8. The vehicle overtakes a cyclist cutting in front of the vehicle on a single lane road	X	X	X			X		X											X
9. Speedbump					X														X
10. 90 degrees turn					X														X
11. Roundabout					X														X
12. Red traffic light	X	X	X								X								
13. Green traffic light					X						X								
14. Toll gate					X				X										
15. Sunshine inside the vehicle (the vehicle asks to raise the sunblind)					X					X					X				
16. The vehicle asks for preferred sitting position based on activity.					X					X	X						X		

3.3. Specific Events

Other than the general events, which will be included in all the use cases, specific events have been also developed. These events are emergency/exceptional situations that do not often happen in a normal drive. The specific events will be included in short scenarios used to evaluate the reaction and the perceptions of users when exceptional cases occur. As with the general events, the specific events have been developed by taking suggestions from all the partners. The events are included Table 6.

1. The vehicle sends a warning that the window cleaners are not working: These specific events include a warning message given by the vehicle that a non-fundamental feature of the car is not working properly. This event will provoke stress on the user; however, it is not supposed to provoke fear for safety. It will also affect the trust and acceptability of the vehicle.

2. The vehicle sends a warning that there has been a major breakdown in the sensory: As specific event 1, this event includes a warning sent to the user. However, in this event, the warning explains that there is a fault in a fundamental feature of the car, which is the sensors capacity of scanning the surroundings. After the warning is displayed, the car will perform a safety stop. The event is supposed to provoke a fear for safety and will affect trust, acceptability and safety perception.

3. The vehicle suffers an accident (minor damage): In this event the car suffers an incident with minor damage to the car. The car is able to follow its predetermined route. The event is supposed to provoke a sense of fear for the safety and influence the acceptance, trust and safety perception of the vehicle.

4. The vehicle suffers an accident (major damage): Similar to specific event 3, the car suffers an incident. However, in this case the damages to the car are major and the car is not able to continue the route. The car will stop. The event will provoke a sense of fear for safety, distress and ager and will affect the acceptability, safety and trust perception.

5. Road works: In this event, the user will encounter road works which will affect the normal behaviour of the vehicle. More precisely, the car will encounter a reduction of the lane width and a forced change of lane. The event will provoke stress and affect dynamic discomfort. Also, acceptability, trust and safety will be impacted.

6. Loud Passenger: This event will include a second user in the car who is going to be louder than normal. This event was decided to provoke acoustic discomfort.

7. The vehicle encounter a standstill queue at a toll gate for 3 minutes: in this event the user will encounter a stand still queue. During the time in the queue, there will be aggressive behaviours by other users in other vehicles (such as horning, intention to overtake…). This event is intended to provoke distress and anger, other than affect the perceived comfort.

8. A pedestrian the street without a zebra crossing: in this specific event the vehicle will encounter a pedestrian crossing (or trying to cross) when it is not permitted, that is far from zebra crossings. In this case the vehicle will stop and let the pedestrian pass.

9. Another vehicle does not respect a yield/stop signs: In this event an external vehicle will enter traffic without respecting a yield/stop sign. The vehicle will stop suddenly. The event will fear for safety and anger, while affecting the perception of acceptability, trust and safety

10. An ambulance/police car in emergency situation asks the way: During the drive the vehicle will make way for an emergency car (ambulance/police/firefighter)**.** This event will provoke a sense of satisfaction and will also influence the sense of acceptability, safety and trust.

11. The vehicle is approaching an entry of a highway and increases the speed slightly above the speed limit in order to integrate safely in the ongoing traffic on highway. Entering a motorway, the vehicle will increase the speed in order to enter the motorway traffic in a safe way. The speed increase will cause a slight break of the speed limit rule. This event is created to provoke a sense of fear for safety and will affect trust and acceptance. Moreover, it will create an ethical dilemma, since the car will break a traffic rule to increase the safety of a maneuver.

12. A motorbike is approaching the AV on the same lane from behind. The AV drives slightly beyond the lane line in order to give safe space to the motorbike. This event will include a motorbike overtaking the user's vehicle. The vehicle will move slightly to give enough space for the motorbike to overtake. However, doing so, the vehicle will pass the lane line, breaking the traffic rule. As with event 12, this event is created to create an ethical dilemma between safety and rule breaking.

Table 6 Specific events and the responses they are meant to evalaute.

Specific Events	Trust	Safety	Acceptability	Environmental sustainability	Comfort and convenience	Fear (Safety)	Fear (Stress)	Distress	Anger	Relief	Satisfaction	Spatial	Thermal	Acoustic	Visual	Tactile	Postural	Hygienic	Dynamic
The vehicle sends a warning that the window cleaner are not working	X		X				X												
The vehicle sends a warning that there has been a major breakdown in the sensory	X	X	X			X		X											
The vehicle suffers an accident (minor damage)	X	X	X			X													
The vehicle suffers an accident (major damage)	X	X	X			X		X	X										
Road works	X	X	X				X												X
Loud passenger					X									X					
The vehicle encounters a standstill queue at a toll gate for 3 minutes				X	X			X	X										
A pedestrian the street without a zebra crossing	X	X	X			X			X										
Another vehicle does not respect a yeld/stop signs.	X	X	X			X			X										X

An ambulance/police car in emergency situation asks the way. The vehicle is approaching an entry of a highway and increases the speed slightly above the speed limit in order to integrate safely in the ongoing traffic on highway.	x X	x X	x X			 X					x								
A motorbike is approaching the AV on the same lane from behind. The AV drives slightly beyond the lane line in order to give safe space to the motorbike	X	X	X			X													

4. USE CASES AS PART OF THE EVALUATION FRAMEWORK

4.1. Use cases in the Evaluation Framework

As described in the previous sections, use cases will form as the primary part of the evaluation framework and act as the tool for assessment of the ALFRED concept and the other components of the SUaaVE project. The evaluation framework is based upon the testing of ALFRED with a comparison being made against a normal connected automated vehicle (CAV) through multiple phases.

As with use cases developed throughout other applications, the use cases forming the evaluation framework will provide detailed definitions joined to the end use of the vehicle to provide a relatability to the test outcomes. Use of common use cases throughout the project will provide the same basis for definition regarding the users and the context of use. This is accompanied with the environmental definition of and the scenario events. In practical terms, the use cases will be the reference for the construction of scenarios for the evaluation of the acceptance of the vehicle by the users, the emotions triggered by the events, and the ethics implications in the use of the vehicle.

Evaluation framework development is subject to the testing demands of the project components and will consequently be defined continuously throughout the project. At a high level, assessment will comprise of two main phases of testing known as first loop and second loop. These two phases encompass formative testing of the models and of vehicle systems, and subsequently provide the basis for summative testing following completion of their development. These two loops can be viewed following the aforementioned concept of situational use cases and use cases defining journeys.

4.1.1. First Loop Evaluation

The first will seek to assess the effectiveness of each model and testing of the hypothesis surrounding each. In addition, there will also be a focus on the specific responses of the ALFRED system in response to model outputs and assess individual interactions by users under specific conditions.

The outcomes of this first loop testing will provide a series of comparative data between the models developed for integration into ALFRED and the corresponding response of the CAV. In addition, it involves the first assessments of the ACE interface and the performance of the dynamic model, both of which will be individually evaluated with comparison made to the CAV response under the same conditions. These will be the basis for conclusions on the success of the projects' first developmental phase. In line with the project aims, this will be with regards to the way that models can respond to and manage specific situations in terms of the users.

In this case, the use of situational use cases offers the means for evaluation under a specific scenario with closely defined conditions. Like with the investigative and development phase, this will provide controllable and repeatable variables within defined test scenarios.

4.1.2. Second Loop Evaluation

The second will take a more global view of the system assessment, seeking to evaluate how the system performs in terms of users when experiencing its use across an entire trip. Like with the first phase this will include testing against the CAV, but with more outcomes given

more focus regarding to how the ALFRED concept might perform in the real world. This stage will include the final evaluations of the vehicle system, with conclusions assessing the overall success of the concept.

With this in mind, use cases for second loop testing will principally take the form of trip scenarios which are representative of an entire user journey. Within this framework, assessment can also be conducted at the situational level, using the same shorter use cases from the first loop. This not only provides a means of comparison between evaluation phases, but also maintains a context to earlier assessment within the second loop.

4.2. Varying types of test scenario for evaluation activities.

4.2.1. Short Scenarios (Situational use cases)

In order to investigate the various attributes contained in the project framework, there was the need of building short use cases able to investigate the reaction and emotion triggered by one specific event. This method will avoid the effect of other type of events which can influence the response to the event presented. These use cases have been called situational use cases, as they are able to investigate and evaluate a specific response to a specific situation. The events included in the situational use cases can be both general or exceptional, depending on the attribute under investigation. The short and specific nature of the situational use cases permits the repetition of the investigation with the same or different subject and the comparison between different vehicle response. As an example, if the attribute under investigation is the response to an event meant to provoke fear, the situation use case will include just one event (e.g. an accident) and the response of different participants can be investigated and compared. Moreover, it is possible to compare the response of the same participant interacting with different vehicles (CAV vs ALFRED)

A model of the situational use cases is presented in Figure 4 below.

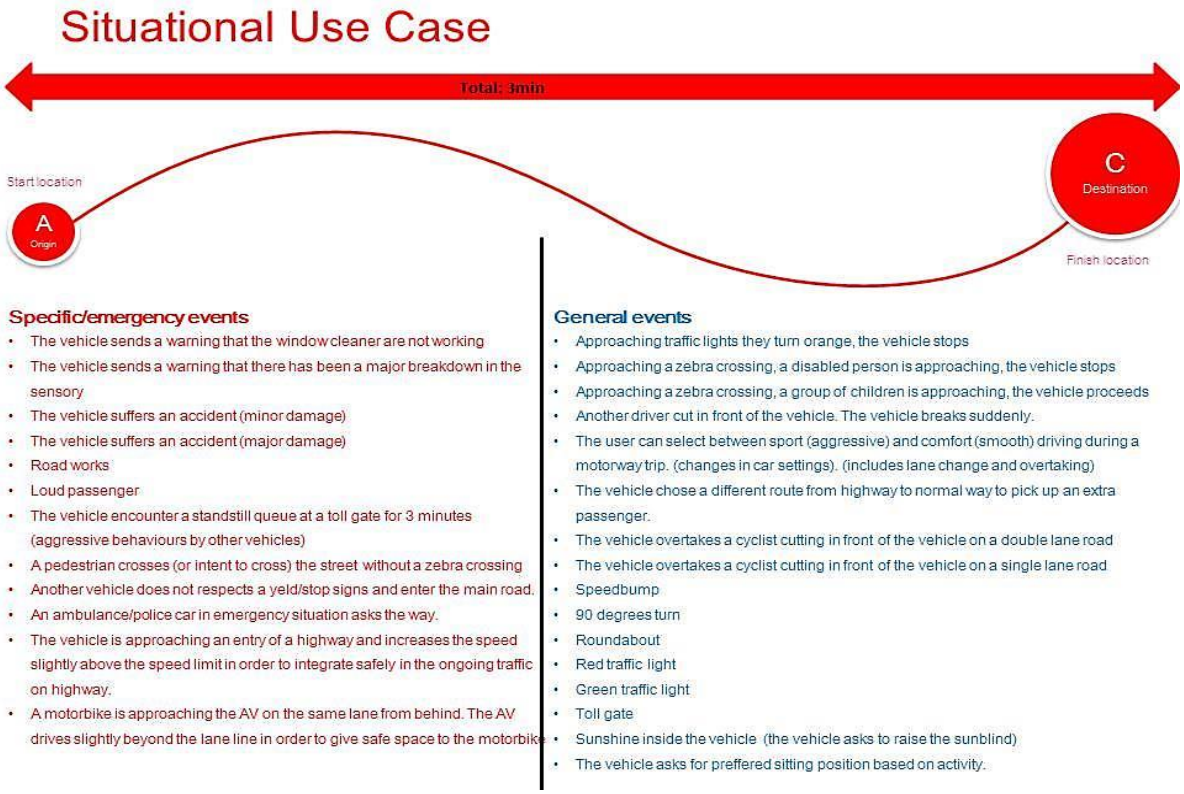

Figure 4 Representation of the situational use cases.

4.2.2. Long scenario (trip use cases)

Other than situational use cases, trip use cases have also been built. These use cases are included in a long scenario, lasting around 15 minutes. In trip use cases, the all the general events will be included. The trip use cases will also involve a specific context and a specific type of user.

The reason underlying the construction of trip use cases is mainly to investigate the different attributes included in the SUaaVE project (e.g. trust, acceptance, comfort…) in a long scenario which aims at representing a normal real life situation.

4.2.3. Use Case A

Users: the main user of the first use case is an adult aged between 25 and 55 years old. The user does not have a driving licence. In addition, another user will be part of this use case, a passenger, unknown to the main user, will enter the vehicle in the middle of the journey. Before entering the car, the user had personal time at home. The user's emotional state is neutral.

Context: the purpose of the journey is to travel to the airport. The occupant will have downtime time and possible inter-occupant interaction after the second user enter the vehicle. The journey will start at home, will have a pick-up stop and end up at the airport transport hub. The journey is depicted in Figure 5 below.

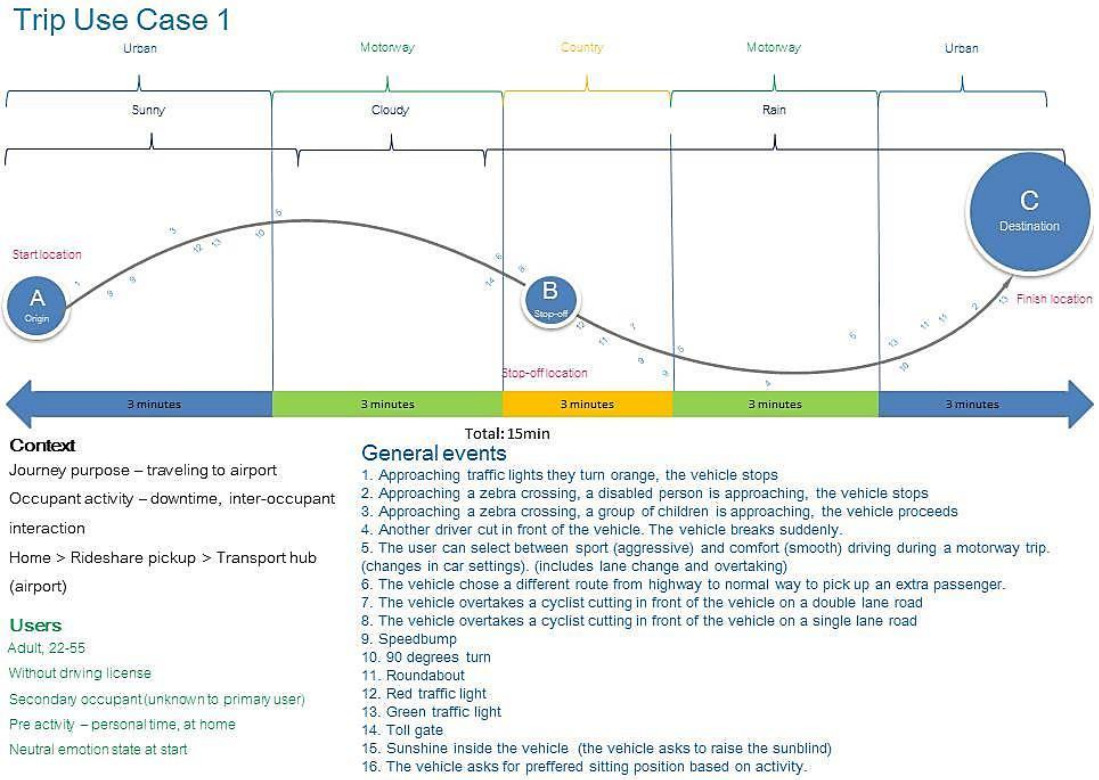

Figure 5 Representation of trip use case 1.

4.2.4. Use Case B

User: The user of the second use case is an adult (aged between 25 and 55) with a driving licence. Before entering the vehicle the user was working. The user has a neutral emotional state. Context: the user will go from the workplace to pick up the children at school. In between the start and final destination, the user will have to stop at a client office. The activity in the vehicle will concern work and media consumption. The use case is depicted in Figure 6.

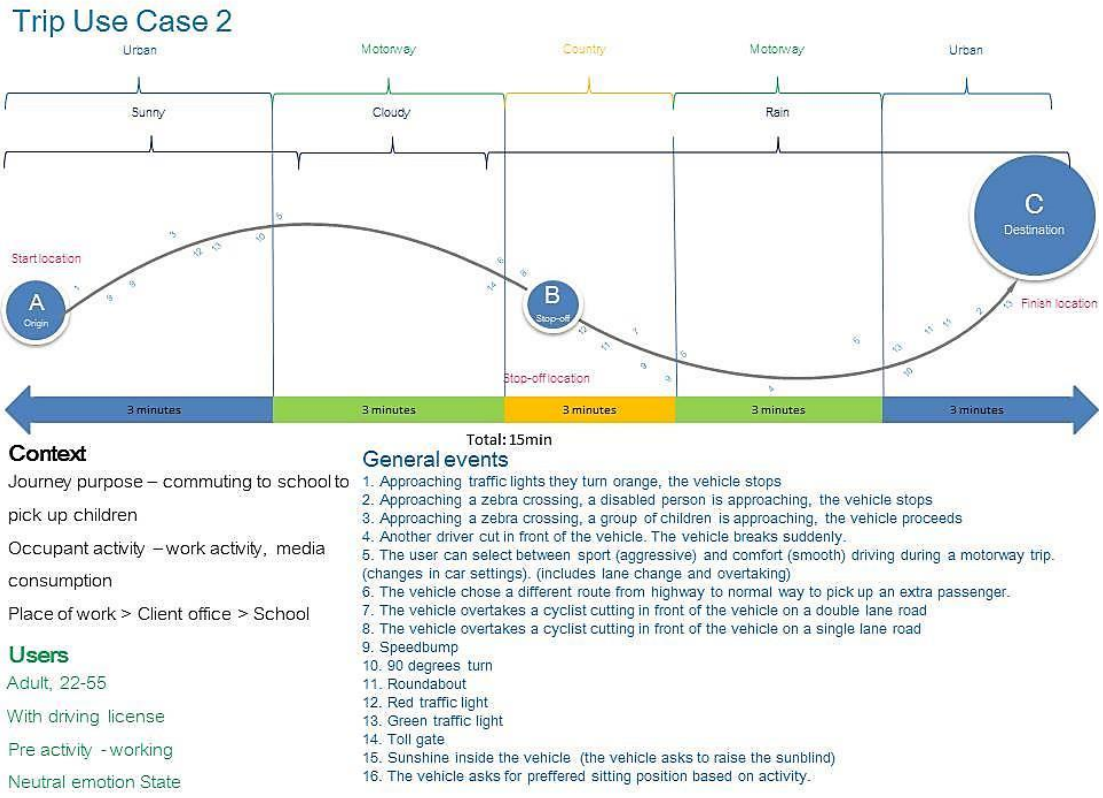

Figure 6 Representation of trip use case 2.

4.2.5. Use Case C

User: the user of the third use case will be an elderly driver aged 65 years or older with or without a driving licence. The user activities before entering the vehicle will be normal activity at home and relaxing activities. The user has a neutral emotional state.

Context: the journey purpose is day to day activities- the journey plan is from home to the doctor and finally to the shopping centre. The user activity in the vehicle will be reading.

The use case is described in detail in the image below (Figure 7).

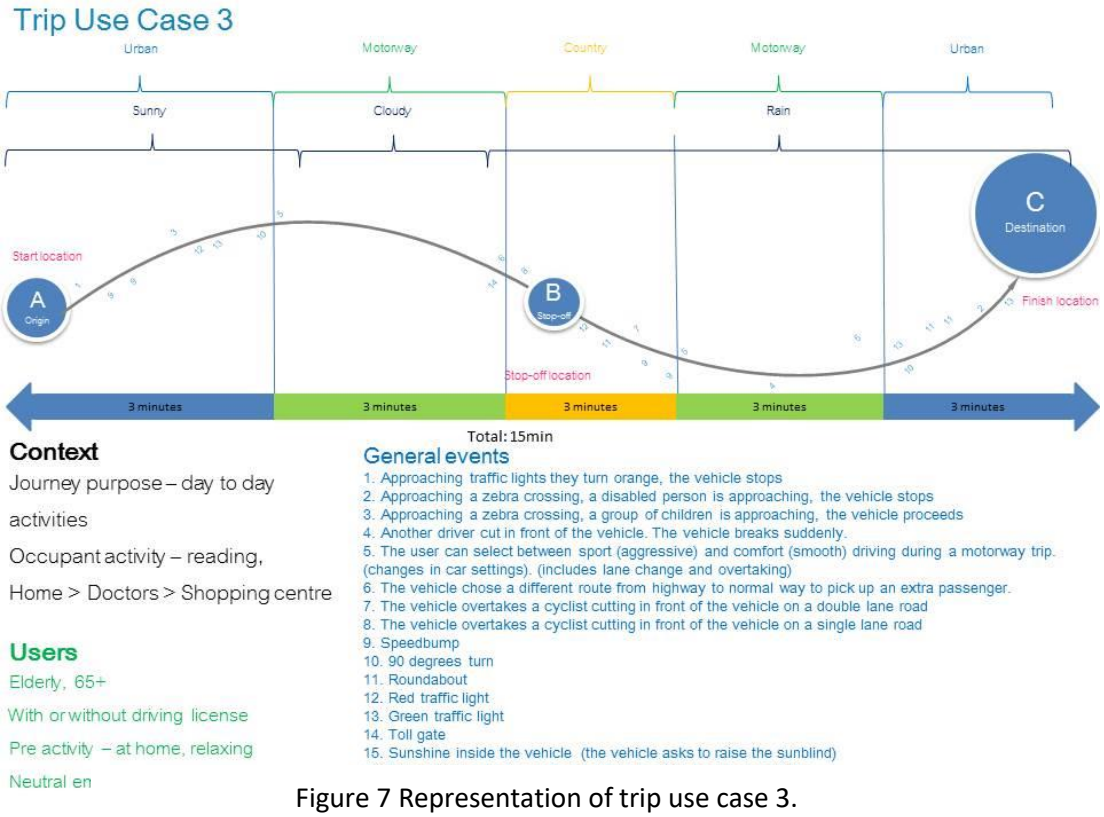

Figure 7 Representation of trip use case 3.

4.3. Use of differing test platforms around what is defined in the use cases

As stated in the introduction section, the V-HCD software will be able to be implemented in various systems depending on the scope of the investigation and the resources needed. In the next sections, the available systems will be described. The V-HCD will be used in all the systems requiring a simulation (static vehicle simulator, HMD) apart from the dynamic driving simulator, where a custom scenario will be created. Video demonstrations will also be taken from the use of V-HCD, but they will be displayed in a 2D screen.

4.3.1. Static vehicle simulation (V-HCD + other)

The static vehicle simulation is a driving simulation that provides a car seat structure included in a CAVE environment. The static vehicle simulator is able to represent a driving situation and immerse the driver in the environment, however, the simulator is static and does not provide any feedback on movement and road conditions. The static vehicle simulator will be used for all the attributes included in the framework apart from dynamic comfort, which needs movement and dynamic feedback.

4.3.2. Dynamic vehicle simulation (V-HCD + other)

The dynamic vehicle simulator is a driving simulator that, other than providing what a static driving simulator does, includes dynamic feedback thanks to a moving platform. This kind of simulators provide a more immersive experience compared to a static driving simulator, but it also has an increased probability of experience motion sickness. The dynamic vehicle simulator will be mainly used for evaluating the dynamic comfort.

4.3.3. HMD simulation (V-HCD + other)

Head Mounted Displays (HMD) are a useful tool to investigate the car interior and simulate events in virtual environments. The advantage of HMD is the ease of use and the possibility to use them in various places. While driving simulators are just available in selected locations, HMD are portable and can be used by all the members. HMD will be used by all the partners to investigate all the attributes of the framework. However, special emphasis will be given to ambient comfort, because of the need for simulating car interiors. Like dynamic vehicle simulators, also HMDs could increase the possibility of experiencing cybersickness.

4.3.4. Video demonstration

Video demonstration will also be used. The use of video is a low-cost, simple way of investigating the opinions of participants on different cases. Compared to the systems described above, the video demonstrations will not have an immersive nature, therefore they will not be used for simulations. However, the use of 2D display will reduce to a minimum the possibility of experiencing motion sickness. Even though video demonstrations can be used for all the attributes (except dynamic comfort) they will be mainly used to evaluate ethics and acceptance.

4.3.5. Textual descriptions of scenarios

The use of textual descriptions of scenario will be the easiest and fastest way of evaluating users' opinions on certain aspects of the framework. The textual descriptions will completely lose the immersion and will not require any special system. However, textual descriptions can be built in a short time, as they do not require any software and scenarios development. The textual description, as the video demonstrations, can be used for all attributes of the framework except for dynamic comfort. However, special use will be made for ethics and acceptance.

5. WP6 TASKS

5.1. In-depth study of ALFRED frameworks

Subtask:	6.1.1	Start month:	M1	End month:	M6	Partner responsible:	IDIADA
Title: In depth study about **hypothesis** from different ALFRED frameworks							
Description: ALFRED common understanding • Research Questions for frameworks: What kind of gaps could this new system cover? • Methodology: Identification of frameworks goals separately. Identification of parameters and main concerns behind. • Partners role, provide information about ALFRED, filling in templates from coordination. • In this holistic activity there is not pretention about human participation.							
Required inputs: Input from WP1 Frameworks main intentions							
Expected outputs: UCs definition ALFRED Expectations and foundations Evaluation framework definition							
Sub milestone or check point: Describe how to validate the success of the subtask or go/not go decision.							

Table 7 Subtask 6.1.1

5.2. Literature Review

Subtask:	6.1.2	Start month:	M1	End month:	M36	Partner responsible:	IDIADA
Title: **Literature review**							
Description: Continuous feedback about Autonomous Driving issues. Papers in this regards, news all around the world about culture issues and Autonomous driving, White paper results, NHTSA, ISO, regulation, etc. • Assumptions • Statements • Challenges • Behaviour patterns for future drivers • Mobility, safety and sustainability perception • …							
Required inputs:							
Expected outputs: UCs definition Evaluation framework guidelines							
Sub milestone or check point: Describe how to validate the success of the subtask or go/not go decision.							

Table 8 Subtask 6.1.2

5.3. Evaluation framework refinement

Subtask:	6.1.3	Start month:	M1	End month:	M30	Partner responsible:	IDIADA
Title: Iterations from evaluation framework refinement. Strengthen support for conclusions							
Description: Strategy for the control of all the outcomes from Alpha ALFRED modules/frameworks (Indicators selection, real world data comparisons). Acceptance, Ethics, emotions frameworks iteration. • Assumptions • Statements • Challenges • …							
Required inputs:							
Expected outputs: Evaluation framework guidelines							

Table 9 Subtask 6.1.3

5.4. Generation of acceptance evaluation framework

Subtask:	6.1.4	Start month:	M30	End month:	M36	Partner responsible:	IDIADA
Title: Generation of an evaluation framework for acceptance assessment and its standardization.							
Description: Strategy for the control of all the outcomes from Continuous feedback about Autonomous Driving issues. Papers in this regards, news all around the world about culture issues and Autonomous driving, White paper results, NHTSA, ISO, regulation, etc. • Assumptions • Statements • Challenges • … Outcomes consolidation proposal							
Required inputs:							
Expected outputs: Evaluation framework guidelines							
Sub milestone or check point: Describe how to validate the success of the subtask or go/not go decision.							

IBV,	RUG,	VED,	TUM,	Bordeaux INP,	IFSTTAR,	CVT,	FICOSA,	CRF	IBV,	RUG,	VED,

Table 10 Subtask 6.1.4

6. CONCLUSION

The principle aim of this deliverable was to give a definition of the use cases which are meant mainly as a tool for the project framework evaluation, but also for other applications as the project progresses.

To do so, first a definition of use cases and use cases characteristics was given in order to lay the foundations for the construction of SUaaVE use cases. In order to do so, the events happening in the use cases and the scenario had to be defined. For the events, the partners identified and added the important events which will provoke specific responses and will permit the evaluation of the ALFRED concept. The scope of the task described in this deliverable was to aggregate and combine these events to create viable use cases. Therefore, sixteen general events and twelve specific events were created. The general events are defined as occurrences happening in usual driving situations, while specific events refer to exceptional situations. The events will be included in the use cases developed as part of the task 6.1. Two types of use cases are described in this deliverable: trip use cases and situational use cases. Situational use cases will be used to elicit specific emotions, will be composed of a short scenario where only one event (exceptional or general) is happening. The event will depend on the responses evaluated and the demands of the specific testing. Trip use cases will be used as general validation of the model, they are composed by a long scenario where several events occur. For the trip events also users and context were defined.

In conclusion, this deliverable achieved the objective described in task 6.1 “Evaluation framework and ALFRED use cases” and defined the use cases and the events for the future evaluation of the ALFRED concept.

7. REFERENCES

Möller, D.P., 2014. Transportation use cases. In *Introduction to Transportation Analysis, Modeling and Simulation* (pp. 229-334). Springer, London.

Vermeeren, A. P., Law, E. L. C., Roto, V., Obrist, M., Hoonhout, J., & Väänänen-Vainio-Mattila, K. (2010, October). User experience evaluation methods: current state and development needs. In *Proceedings of the 6th Nordic conference on human-computer interaction: Extending boundaries* (pp. 521-530). ACM.

Wachenfeld, W., Winner, H., Gerdes, J. C., Lenz, B., Maurer, M., Beiker, S., Fraedrich, E., & Winkle, T. (2016). Use cases for autonomous driving. In *Autonomous driving* (pp. 9-37). Springer, Berlin, Heidelberg.

Wilson, J. R., & Sharples, S. (2015). *Evaluation of human work*. CRC press.

APPENDICES

Appendix 1 Complete table of events suggested by each partner

	IRUG						IBV						IDIADA (comfort)					
Generic Events	Trust	Safety	Acceptability	Environmental sustainability	Comfort and convenience	Fear (Safety)	Fear (Stress)	Distress	Anger	Relief	Satisfaction	Spatial	Thermal	Acoustic	Visual	Tactile	Postural	Hygienic
Interaction with a group of children crossing the street	X	X	X				X											
Interaction with a cyclist	X	X	X			X												
Interaction with a handicapped pedestrian	X	X	X			X												
Complex traffic environment vs simple traffic environment	X	X	X				X				X							
Approaching to traffic lights	X	X	X			X												
Busy intersection	X	X	X			X	X											
Stopping to get other passengers					X						X							
Vehicle dynamics: customizable Smooth VS aggressive driving	X	X	X			X				X								
Area with traffic lights customizable. To create scenarios with fluent driving	X	X	X		X		X			X	X							

VS slow driving to trigger emotions.																		
Rain/Fog. To create scenarios with low visibility VS sunny day	X	X	X	X	X	X							X		X			
Other driver commits an infringement that affects the passenger drive	X	X	X						X									
Other driver commits an infringement that affects the passenger safety perception	X	X	X			X												
Pedestrian approaching to a crossing zebra. (but CAV can pass before) CAV stops VS CAV does not stop	X	X	X		X			X			X							
Start																		
Speedbump					X													
Passenger pick up			X		X							X						
Car blocking (Low speed double lane change)	X	X	X			X												
90deg corners			X		X													
Roundabout					X													
Country Road Section					X													
Mid Speed Obstacle Avoidance	X	X	X			X												
Hard braking	X	X	X			X												
Deterministic input																		

highway entry					X													
toll gate					X	X												
Highway Lane Chge	X	X	X		X	X												
Highway exit					X	X												
Sunshine inside the vehicle (ALFRED asks to raise the sunblind)					X				X	X					X			
ALFRED asks for preffered sitting position based on activity.					X					X							X	
Cyclist cut-in / Motorcycle cut-in	X	X	X			X			X									
Zebra crossing with an emergency braking because of a pedestrian, a traffic lights yellow/red… a VRU crossing with yellow/red	X	X	X			X	X		X									
Pedestrian encounter with no zebra crossing	X	X	X			X	X		X									
Toll payment stop in a highway					X				X									
Other car aggressive driving during a traffic jam:	X	X	X				X		X									
- Roundabout, Traffic lights, Bumpers, Railway crossing, Yield/stops, Zebra crossing					X													

Consortium:

Project Title:
SUpporting acceptance of automated VEhicle

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814999