OPERATIONAL DESIGN DOMAIN

Academy of Robotics

OPERATIONAL DESIGN DOMAIN (O.D.D)

Foreword

As per the definition provided in the - PAS 1883:2020 - legislation, the Operational design domain (ODD) is defined as;

"**Operating conditions** under which a given driving automation system or feature thereof is specifically designed to function"

The intention of this documentation is act a living document that will be updated to both define the attributes relative to the ODD, as defined by the guidance provided in the - PAS 1883:2020 - documentation, and to further provide updates on the ODD of the Kar-Go vehicle. It is important to note that the Kar-Go's functionality can be split into two elements;

- The Kar-Go vehicle as an autonomous vehicle with all the internal and external attributes of an ADS
- The Kar-Go ADS packaged as a separate entity that can function as either an Advanced Driver Assistance System (ADAS) or ADS for a separate vehicle to Kar-Go

As a result, the following documentation will cover the ODD capabilities of the Kar-Go vehicle and its ADS, with the assumption that the detection and perception capabilities associated with such, can also be applied in the instance of developing an ODD for an ADAS system.

Introduction

Establishing the Operational design domain of an autonomous vehicle and its supporting ADS is fundamental for ensuring safe practices surrounding the trialing and deployment of autonomous vehicles and ADS/ADAS systems. defined constraints and capabilitiesnecessary for presenting a robust ODD. It is important to develop an ODD so that capabilities and constraints can accurately, and in detail, be conveyed to relevant stakeholders and trialing organisations.

The ODD is not just a checklist of constraints and capabilities, but also a tool for reviewing the development of associated ADS and monitoring high-performing areas, areas that can be improved and areas to develop. The ODD sets the current benchmark for the operating conditions that must be considered when conducting any form of autonomous vehicle or system testing on live roads and can act as an extensive guidance on the capabilities of these systems.

A framework for establishing these parameters and the acceptable grounds for the operation of an autonomous vehicle or ADS is further required for the safe and compliant testing of aforementioned technologies. With clearly defined constraints and capabilities being necessary for presenting a robust ODD.

Purpose

The purpose of this documentation is to detail the ODD of the Kar-Go autonomous vehicle and the associated ADS. This includes the ODD of the Kar-Go vehicle in autonomous driving trialing scenarios as well as the the ADS software in semi-autonomous driving trialing scenarios where the vehicle may be manually driven by a safety driver whilst all autonomous detection and perception software is running and a safety operator is present using a overseeing Command Hub.

To be act as a living document, the procedural review and updating of the document ensures that ODD benchmarks are developed and reported prior to every trial/project associated with the Kar-Go vehicle and ADS, to act as a log that not only details the ODD at the time of a trial, but also provides evidence of previous ODD capabilities and constraints in prior trials, through attached appendices. Maintaining this document further allows for additional, extensive ODD details to be provided in project and trial safety cases.

In order to assist in the development of a common ODD, this documentation shall provide information as it pertains to Academy of Robotics and the ODD of the Kar-Go vehicle and ADS. Following the support and guidelines provided by the - PAS 1883:2020 - documentation, to help in creating a unifying framework for the presentation of information as it pertains to the development of autonomous vehicles and systems.

Scope

Academy of Robotics has developed both an autonomous vehicle (Kar-Go) as well as supporting ADS software. The applicability of this documentation applies to both the ODD of the Kar-Go vehicle, the ADS and its functionality as a separate ADAS entity. The definitions and guidelines adhered to within this documentation are in relation to the - PAS 1883:2020 - put forward by the British Standards Institute (BIS) and the classifications of the - Safety Case Framework 2.0 - provided by Zenzic.

Definitions

The following definitions that apply to this document are provided within the - PAS 1883:2020 - documentation regarding the taxonomy of the ODD, with additions from Academy of Robotics.

Advanced Driver Assistance System
A hierarchy of safety systems that operate with one another to enhance vehicle safety through automated alerts provided to the driver about potential problems and collisions.

Automated Driving System (ADS)
Hardware and software that are collectively capable of performing.

Operational Design Domain
The conditions in which an automated driving system is intended to function.

Kar-Go Vehicle
The Kar-Go vehicle is an autonomous vehicle developed for the purpose of completing autonomous deliveries.

References

The foundation of this documentation follows the information and suggested guidelines suggested within;
- British Standards Institute (BS). (2020) PAS 1883:2020, Operational design domain (ODD) taxonomy for an automated driving system (ASD), BSI
- TRL. (2020), Safety Case Framework Report 2.0, Zenzic

Operation design domain of the Kar-Go vehicle and associated ADS

Attributes of the ODD:

In guidance with - PAS 1883:2020 - and in order to develop a common ODD. The ODD has been, at the top level, classified into the following three attributes;

- Scenery: Accounts for the non-movable elements associated with the operating environment of both vehicle and software, an example of this being traffic lights.

- Environmental Conditions: Applies to weather and atmospheric conditions that may be apparent within the operating environment of both vehicle and software.

- Dynamic Elements: Considered to be the movable elements within the operating environment, an example of this being traffic.

Scenery

Scenery, as defined by the non-movable elements associated with the operating environment for an autonomous vehicle and ADS, is categorized with the following general attributes:

A) Zones
B) Driveable Area
C) Roundabouts
D) Junctions
E) Special Structures
F) Fixed Road Structures
G) Temporary Road Structures

Zones

This refers to regions (zones) within the operating environment which may possess a special configuration that requires additional capabilities from an autonomous vehicle or ADS. The Kar-Go vehicle and associated ADS can operate within conditions which feature foliage in zones, given the correct pre-training.

Geo-Fenced Areas

Areas in which geo-fencing are utilised are within the operating conditions of the Kar-Go vehicle and ADS. Where a level of communication may be required between the vehicle and an externally developed Geo-Fence, the functionality i s possible but would be explained in a more detailed sense in the project plan relative to the operating environment in which this communication may be required. Internal Geo-Fencing relative to the location tracking and sending/receiving of actions via programming to the Kar-Go autonomous vehicle and ADS, is currently capable up to a 5km radius.

Traffic Management Zones

Pre-training of the Kar-Go vehicle and ADS, allow for operating within traffic management zones if they fall within the specified route that the software is trained upon for the purpose of the project/trial. Further real-time detection and perception capabilities allow for operating within these zones regardless of the pre-training. However, only pre-trained traffic management zones are within the current ODD of the Kar-Go vehicle and ADS.

School Zones

At the current, School Zones are a constraint on the ODD of the Kar-Go vehicle and ADS. This is as these zones do not factor into planned trial routes and thus the systems, whilst capable of operating in these zones, have not been calibrated at a level that would explicitly place them within the ODD of the Kar-Go vehicle and ADS.

Regions or Counties

The Kar-Go vehicle and ADS is capable of operating on unmarked, urban and suburban roads within the UK. With an ability to operate on roads within Europe on the provision of correct approval and pre-training the significant differing factors within the intended trial/project area.

Interference zones

Interference zones relate to operating environments where there could be an assumed level of interference as a result of environmental non-movable features. This could be dense foliage that creates visual noise that hinders the capabilities of the detection and perception software or areas in which tall buildings or large structures can lead to a loss of a positioning signal.

The Kar-Go vehicle can operate within interference zones where a loss of positioning signal may be considered a risk. This is a result of a pre-training process in which the operating environment is already captured before any autonomous operation. This route information is collected within video datasets which are processed through autonomous software and associated detection and perception modules. This allows for the vehicle and its software to understand and have experience of navigating the road and its features regardless of whether or not it has a positioning signal. There is further training using simulators to generate the route in a safe off-road test environment to further train the vehicle to the variables present within the operating area.

Areas in which a loss of positioning signal, whilst being areas in which the Kar-Go vehicle and its associated software can operate within, are to be considered within the ODD or outside of it, dependent on the goals of the project and its attributed objectives. For example, in a project that focuses on monitoring the vehicle as it completes a task, it may be a requirement to maintain a constant positioning signal. Whilst, in a project which explores the driving and software capabilities of the Kar-Go vehicle, in operating environments that are prone to a loss of signal, these environments may be considered within the ODD.

Drivable area

Drivable Area

Drivable area accommodates for the type of surface, its geometry and state that is within the ODD of the autonomous vehicle and ADS. It also accounts for surfaces that may not explicitly be roads when considering that of an ADS. For the purpose of developing the ODD for the Kar-Go vehicle and ADS, the primary assumption will be that all of the following general attributes that are detailed are relative to roads;

1. Driveable Area Type
2. Drivable Area Geometry
3. Drivable Area Lane Specification
4. Driveable Area Signs
5. Driveable Area Edge
6. Driveable Area Surface

Drivable Area Type

The ODD of the Kar-Go vehicle and ADS, as it pertains to driveable area type allow for operation on the following types of road;

1. Radial Roads
2. Distributor Roads
3. Minor Roads
4. Slip Roads
5. Parking
6. Shared Space

Constraints

Whilst motorways could theoretically be inside the ODD of the Kar-Go vehicle and ADS, they are not at the present. This is the result of a focus on operating one unmarked, urban and suburban roads and all projects/trials being within an operating environment where motorways do not feature. Motorways also present challenges as a result of high speed traffic and issues with halting, managing a fault mid motorway operations.

Drivable Area Geometry

The road layout can be divided into three key attributes to surmise the drivable area geometry within the ODD of the Kar-Go vehicle and ADS. These attributes are as follows;

- **Horizontal Plane:** The Kar-Go vehicle can autonomously operate on horizontal curvatures up to 60 degrees.

- **Longitudinal Plane**: The Kar-Go vehicle can autonomously operate on a vertical uphill gradient of up to 30 degrees with a downhill gradient of up to 30 degrees.

- **Traverse Plane:** The Kar-Go vehicle can autonomously operate in scenarios with no pavements and within 10 cm of a detected road edge.

Driveable Area Lane Specification

Lane specification refers to the number of lanes, the dimensions of lanes, direction of travel and type of lane that is within the ODD of the autonomous vehicle. The Kar-Go vehicle and ADS is capable of operating within up to 4 lanes with the provision that the dimensions of these lanes are wider than 2.5 metres long.
Furthermore, the Kar-Go vehicle and ADS is capable of operating on lanes where the direction of travel provides both right-hand traffic as well as left-hand traffic.

The Kar-Go vehicle and ADS is capable of operating within the following lane types;

1. Traffic lane
2. Tram lane
3. Emergency Lane
4. Other Special purpose lane

Constraints

The following types of lane are not within the ODD of the Kar-Go vehicle and ADS;

1. Bus lane
2. Cycle lane

Drivable Area Signs

Area signs fall into the following categories; information, regulatory, warning. With durations of the signs operation time split between; full-time and temporary. The Kar-Go vehicle and ADS software is capable of distinguishing all types of road-sign. Given that pre-training has been applied to the vehicle to register the area signs that may feature within the operating environment. All signs pre-trained onto the Kar-Go ADS software will be memorised by the system so that the software retains its understanding of the sign and ability to detect them when present on the road.

Drivable Area Edge

The Kar-Go vehicle and ADS software is capable of operating with the ability to distinguish the following classifications of attributes relative to driveable area edge;

1. Line markers
2. Shoulder (paved or gravel)
3. Shoulder (grass)
4. Solid barriers (e.g grating, rails, curb, cones)
5. Temporary line markers
6. None

This further extends to the following types or road edge as classified by Academy of Robotics;

1. Unmarked lanes
2. Multi-lane roads
3. Divided
4. Undivided

All of which are within the ODD of the Kar-Go vehicle and ADS.

Drivable Area Surface

The Kar-Go vehicle and associated ADS is capable of operating within operating environments in which the following area surface types feature;

1. Segmented (e.g. granite setts, cobblestones)

Constraints

The following area surface types are not within the ODD of the Kar-Go autonomous vehicle and ADS;

1. Loose (e.g. gravel, earth, sand)
2. Uniform (e.g. asphalt)

Drivable Area Surface Conditions

The following surface conditions are within the ODD of the Kar-Go vehicle and ADS;

1. Mirage
2. Snow on drivable area (dependent on depth of snow)
3. Wet road
4. Standing water (dependent on depth of standing water)

Constraints

The following surface conditions are not within the ODD of the Kar-Go vehicle and ADS;

1. Icy
2. Flooded roadways
3. Surface Contamination

Roundabouts

Drivable Area Surface

The Kar-Go vehicle and associated ADS is capable of operating within environments that feature roundabouts with the following attributes associated with them;

1. Normal
2. Compact
3. Double
4. Large
5. Mini

This applies to roundabouts that are both signalized and non-signalized, with the Kar-Go vehicle and associated ADS capable of operating on both.

Junctions

The Kar-Go vehicle and associated ADS is capable of operating within environments that feature junctions with these specific attributes;

1. T-junctions
2. Staggered
3. Y-junction
4. Crossroads
5. Grade separated

Special Structures

The Kar-Go vehicle and associated ADS is capable of operating within environments that feature these special structures;

1. Automatic access control
2. Bridges
3. Pedestrian crossing
4. Rail crossing

Constraints

The following types of special structure are not within the ODD of the Kar-Go vehicle and ADS;

1. Tunnels
2. Toll Plazas

Fixed Structures

The Kar-Go vehicle and associated ADS is capable of operating within environments that feature the following fixed structures;

1. Buildings
2. Street lights
3. Street furniture
4. Vegetation

Temporary Structures

Temporary structures are no fixed and often sporadic variables that may become present within the operating area as non-movable elements. The Kar-Go vehicle and ADS is capable of factoring construction site detours into the ODD with prior surveying as this is relative to the requirement for a predefined route. Temporary road signage and refuse collection are within the ODD of the Kar-Go vehicle and ADS, whilst road works is dependent on the size and extent of the area it occupies.

Environmental Conditions

Environmental conditions cover variables that include weather effects and levels of illumination and particulates present that require a response from an ADS system. Whilst this section will predominantly look at the operating conditions of the Kar-Go ADS under these circumstances, it is important to note that adverse weather, illumination and particulate conditions determine whether or not an autonomous vehicle can run in the same way as a manually driven vehicle. As such, when factoring in the safe operating conditions of the Kar-Go vehicle, as an autonomous vehicle, considerations are made to both the safe and available functionality of the ADS and the level of acceptable safety relative to having a vehicle driving on the road.

Weather

Categorisation of weather within this section can be broken down into the following sections;

- Rainfall
- Wind
- Snowfall
- Particulates

It is important to note that these conditions can be assessed individually but also as a culmination of several weather conditions combined together.

All measurements relative to weather conditions present in this documentation are in guidance with the - PAS 1883:2020 - documentation and have been used to accurately detail the ODD of the Kar-Go vehicle in reference to weather conditions and to establish a common ODD framework for stakeholders and interested parties.

Rainfall

Rainfall and its intensity, shall be specified in the units of mm/h (millimetres per hour.) This will include definitions over the interval and spatial scale as part of the intensity of the rainfall. The significant natural variability that is associated with rainfall over time and distance means that it can impact autonomous vehicles and their ADS at varying degrees dependent on the intensity, with many potential changes in this variability over a long or short period of time as well as distance. As such, this section will demonstrate the appropriate rain thresholds in which the ADS can function and the Kar-Go vehicle can safely operate.

The varying degrees of rainfall can contribute to noise within the detection and perception software associated with the Kar-Go vehicle and its ADS. Due to this, rainfall must be measured and accounted for with assumption of a potentially higher density when assessing expected rainfall during operations.

In order to develop the ODD for the Kar-Go autonomous vehicle and ADS with respect to rainfall. Measurements of rainfall, when present, include the average rainfall intensity as determined by a meteorological rain gauge over a period of one minute as well as average rainfall in a rainfall radar pixel of a size specified in km. This can be performed when rainfall is not present in the operating environment but is within a close proximity as a preemptive measurement, and also when rainfall occurs in the operating environment.

In guidance with - PAS 1883:2020 - the defined classifications of rainfall applicable to this document are as follows;

1. **Light rain:** When the precipitation rate is ← 2.5 mm/h
2. **Moderate rain:** When the precipitation rate is between 2.5 mm/h and 7.6 mm/h
3. **Heavy rain:** When the precipitation rate is between 7.6 mm/h and 50 mm/h
4. **Violent rain:** When the precipitation rate is between 50 mm/h and 100 mm/h
5. **Cloudburst:** When the precipitation rate is ← 100 mm/h

The ODD of the Kar-Go vehicle and associated ADS is currently capable of operating in conditions up to that of Moderate rain.

Wind

Wind speed, as specified in units of m/s. Is considered as an average over a specified time interval.

Categorizations of wind speed are taken from the Beaufort scale which measures speeds strictly from a position of 10 metres above flat ground. The following values are made to the nearest 0.1m/s which accounts for the variability of wind and the scale of precisions associated with the measurements. The categorizations of wind speed are as follows;

1. **Calm:** 0-0.2 m/s
2. **Light air**: 0.3 - 1.5m/s
3. **Light breeze:** 1.6 - 3.3m/s
4. **Gentle breeze:** 3.4 - 5.4 m/s
5. **Moderate breeze:** 5.5 - 7.9 m/s
6. **Fresh breeze:** 8.0 - 10.7 m/s
7. **Strong breeze:** 10.5 - 13.8 m/s
8. **Near gale:** 13.9 - 17.1 m/s
9. **Gale:** 17.2 - 20.7 m/s
10. **Strong gale:** 20.8 - 24.4 m/s
11. **Storm:** 24.5 - 28.4 m/s
12. **Violent storm:** 28.5 - 32.6 m/s
13. **Hurricane force:** $\rightarrow$ 32.7 m/s

The ODD of the Kar-Go vehicle and associated ADS is currently capable of operating in conditions of up to that of Fresh breeze.

Snowfall

Intensity of snowfall is inferred and determined from visibility regarded from a human perspective. It is important to note that defining meaningful snowfall rates is a challenge, with visibility, in some cases, not necessarily linked to the accretion on surfaces. As such, when assessing the ODD of Kar-Go and associated ADS in regards to snowfall, considerations are also considered to the driveable area surface which may include snow on a drivable area. Classifications of snowfall are as follows;

1. **Light snow:** Where visibility is greater than 1 km
2. **Moderate snow:** Where visibility restrictions are between 0.5km and 1km
3. **Heavy snow:** Where visibility is less than 0.5km

The ODD of the Kar-Go vehicle and associated ADS is currently capable of operating in conditions of up to that of Light snow, however this would also factor in the accretion of surfaces and that performing DDT were within the ODD attributed to the driveable area type.

Particulates

The impact of particulates, which is matter in the form of miniscule separate particles. Is expressed most commonly in terms of visibility when assessing the level of impact on detection and perception software. This can also be regarded as noise on the image planes. Related to human perception, visibility entails that particulate measurements are only applicable to sensors operating at human-visible wavelengths. As such, to determine the degree of obscuration, requires a dependency on measuring the amount of particulate matter, the sensor wavelength and the size and distribution of particles present.

Current levels of determining the visibility regarding particulates involves that of utilising human perception as a tool for measurements. With preliminary testing of the Kar-Go ADS yielding a capability of operating in environments with the following particles present at a level of visibility deemed acceptable by human perception. The particulates are as following;

1. Marine (coastal areas only)
2. Sand
3. Smoke

Constraints

The following particulate classifications are not within the ODD of the Kar-Go vehicle and ADS.

1. Non-precipitating water droplets or ice crystals (i,e mist/fog)
2. Dust
3. Severe Pollution
4. Volcanic ash

↓

Illumination

Impacts of illumination can be of both a beneficial and detrimental nature. With brightness providing a greater level of visibility and shadowing and glare decreasing the level of visibility. Illumination is categorized with the following attributes;

1. Day
2. Night or low-ambient lighting conditions
3. Cloudiness
4. Artificial illumination

Day

During daytime, which is defined as a condition where the ambient illuminance is greater than 2000 lux (lx), further considering that the sun can be in front, behind, at the right side or left side. The following attributes are considered when determining the daytime ODD;

1. Elevation of the sun above the horizon (as a range in degrees)
2. Position of the sun

The Kar-Go autonomous vehicle and associated ADS is capable of operating within all daytime conditions where the level of illuminance is greater than 2000lx, with the elevation of the sun and its position in the sky of no detriment to the ODD.

Night or low-ambient lighting conditions

Night time is a condition in which the ambient illuminance is less than 1lx. Low-ambient lighting condition is when the ambient light in at a level between night (1lx) and day

The Kar-Go vehicle and associated ADS can perform in low-ambient conditions provided the lux (lx) is higher than 107.

Cloudiness

Cloud cover refers to the amount of sky that is covered by clouds. This can affect illumination during daytime conditions and as such, can influence the varying level of visibility present within an operating environment.

Levels of cloud coverage are defined as the following;

Clear - no possibility of cloud fully or partially obscuring the sun
Partly cloudy: some possibility of a direct path of sunlight to the Kar-Go vehicle between clouds
Overcast: there are no breaks in cloud coverage

Cloud cover can further be classified using units of okta;

Clear: sky clear: 0 - 1 oktas
Partly cloudy: few clouds: 1 - 2 oktas
Partly cloudy: scattered clouds: 3 - 4 oktas
Partly cloudy: broken clouds: 5 - 7 oktas
Overcast: 8 oktas

The Kar-Go vehicle and associated ADS is capable of operating in all levels of cloudiness on the provision that cloud cover does not lower the level of lx to $\leftarrow$ 107.

Artificial Illumination

Artificial illumination accounts for the illumination provided by streetlights and oncoming vehicles present within the operating environment.

At the present, driving in night time conditions is a constraint within the ODD of the Kar-Go autonomous vehicle and associated ADS. However, any level of artificial illumination that is assisted by ambient sunlight and has higher than 107(lx) is within the ODD.

Connectivity

This details the ability for the autonomous vehicle and ADS, to receive/transmit data to an external position. This can be for the process of communicating or the location tracking of the vehicle. Connectivity is an important element of the ODD as it allows for the safe monitoring, interaction and reporting of the operations of an autonomous vehicle and ADS.

Communication

Communication is broken down into the following two elements;

Vehicle to infrastructure (V2I) is within the ODD of the Kar-Go vehicle and ADS. The Kar-Go vehicle transmits data to an external command and control center using one or more of the following technologies:

1. 4g Cellular
2. 5g cellular
3. 802.11p Wifi

The external command and control center can mean one or more of the following:

1. External laptop
2. External server

Traffic

Traffic is classified by the following attributes;

1. Density of agents
2. Volume of traffic
3. Flow rate
4. Agent type
5. Presence of special vehicles (e.g ambulances or police vehicles.)

The Kar-Go vehicle and ADS is capable of operating in traffic conditions where the density, volume and flow rate can be considered heavy. Furthermore, the detection and navigation software can detect all agent types and is trained in responding to the presence of special vehicles on the road.

Subject Vehicle

The following attributes associated with the subject vehicle detail the parameters within the ODD;

Route

The Kar-Go vehicle and ADS can operate on routes that are pre-defined. Unseen routes are not within the ODD.

Navigational Capability

The Kar-Go vehicle can perform left and right turns at an angle up to 60 degrees and is capable of switching lanes. This is supported by the ADS.

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Subject Vehicle Safety Features

Safety features and assurance of risk mitigation systems are integral to the ODD. The Kar-Go vehicle has its own capability of fault reporting, which is recorded in log files and identifiable in signals transmitted by the vehicle in certain instances. Furthermore, the ADS has its own form of fault reporting which is stored in log files.

Remote access is available to the Kar-Go vehicle and its ADS to allow for the control of the vehicle to be taken from the Command Hub which is a remote location. There is also hardware integrated that allows for the control to be taken manually by a present driver/ safety driver.

Appendix A - General ODD of Kar-Go autonomous vehicle and associated ADS

Date: 19/8/2020

The purpose of this appendix is to provide a brief, easy to use checklist which details all attributes of the ODD as established within - PAS 1883:2020 - to highlight the capabilities of the Kar-Go vehicle and ADS.

Further checklists may be completed relative to particular projects/trials and developments to the autonomous vehicle and ADS that increase the capabilities within the ODD.

It is the purpose of this appendix and checklist to not only detail the ODD capabilities of the Kar-Go vehicle and ADS at the time of this appendixes creation, but to also exist as a log of changes in the ODD over a review and re-established time period.

Attribute	Sub-attribute	Sub-attribute	Capability
Drivable area signs	Type	Regulatory	Yes
		Warning	Yes
		Information	Yes
Drivable Area Edge	Time of operation	Part-Time	Yes with (pre training)
		Full-Time	Yes with (pre training)
	State	Variable	Yes
		Uniform	Yes
	Line markers	-	Yes
	Shoulder (paved or gravel)		Yes
	Shoulder (grass)		Yes
	Solid barriers (e.g. grating, rails, curb, cones)		Yes
	Temporary line markers		Yes
	None		No
Roundabouts	Normal	Signalized	Yes
		Non-signalized	Yes
	Compact	Signalized	Yes
		Non-signalized	Yes
	Double	Signalized	Yes
		Non-signalized	Yes
	Large	Signalized	Yes
		Non-signalized	Yes

Attribute	Sub-attribute	Sub-attribute	Capability
Driveable area geometry	Horizontal plane	Straight roads	Yes
		Curves	Upto 60 degrees
	Vertical plane	Up-slope	30 degree
		Down-slope	30 degree
		Level plane	NA
	Cross-section	Divided. Undivided	Yes
		Pavement	No
		Barrier on the edge	Needs 10 cm clearance
		Types of lanes together	Yes
Drivable area surface conditions	Tilcy	–	No
	Flooded roadways		No
	Mirage		Yes
	Snow on drivable area		Yes
	Standing water		Yes
	Wet road		Yes
	Surface contamination		Dependent on extent

Attribute	Sub-attribute	Sub-attribute	Capability
Drivable area signs	Type	Regulatory	Yes
		Warning	Yes
		Information	Yes
Drivable Area Edge	Time of operation	Part-Time	Yes with (pre training)
		Full-Time	Yes with (pre training)
	State	Variable	Yes
		Uniform	Yes
	Line markers	-	Yes
	Shoulder (paved or gravel)		Yes
	Shoulder (grass)		Yes
	Solid barriers (e.g. grating, rails, curb, cones)		Yes
	Temporary line markers		Yes
	None		No
Roundabouts	Normal	Signalized	Yes
		Non-signalized	Yes
	Compact	Signalized	Yes
		Non-signalized	Yes
	Double	Signalized	Yes
		Non-signalized	Yes
	Large	Signalized	Yes
		Non-signalized	Yes

Attribute	Sub-attribute	Sub-attribute	Capability
Roundabouts	Mini	Signalized	Yes
		Non-signalized	Yes
Intersections	T-junction	-	Yes
	Staggered		Yes
	Y-junction		Yes
	Crossroads		Yes
	Grade separated		With training
Special structures	Automatic access control		No
			Yes
	Bridges		Yes
	Pedestrian crossings		Yes
	Rail crossings		Yes
	Tunnels		No
	Toll Plaza		
Fixed road structures	Buildings		Yes
	Street lights		Yes
	Street furniture		Yes
	Vegetation		Yes
Temporary road structures	Construction site Detours		With prior surveying
	Refuse collection		Yes
	Road works		Dependent on extent
	Road signage		Yes

Environmental Conditions (Weather)

Attribute	Sub-attribute	Sub-attribute	Capability
Rainfall millimeters per hour (mm/h)	Light rain <2.5 mm/h	-	Yes
	Moderate rain 2.5 - 7.6 mm/h		Yes
	Heavy rain 7.6 - 50 mm/h		No
	Violent rain 50 - 100 mm/h		No
	Cloudburst < 100 mm/h		No
Wind metres per second (m/s)	Calm 0-0.2 m/s		Yes
	Light air 0.3-1.5 m/s		Yes
	Light breeze 1.6-3.3 m/s		Yes
	Gentle breeze 3.4-5.4m/s		Yes
	Moderate breeze 5.5-7.9 m/s		Yes
	Fresh breeze 8.0-10.7 m/s		Yes
	Strong breeze 10.5-13.8 m/s		No
	Near gale 13.9-17.1 m/s		No
	Gale 17.2-20.7 m/s		No
	Strong gale 20.8-24.4 m/s		No
	Storm 24.5-28.4 m/s		No

Environmental Conditions (Weather)

Attribute	Sub-attribute	Sub-attribute	Capability
Wind metres per second (m/s) cont.	Violent Storm 28.5-32.6 m/s	-	No
	Hurricane Force > 32.7 m/s		No
Snowfall (visibility)	Light snow < 1km		Yes
	Moderate snow 0.5-1km		No
	Heavy snow > 0.5km		No
Particulates	Marine (coastal areas only)		Yes
	Non-precipitating water droplets or ice crystals (i.e. mist/fog)		Only if > 20 m visibility
	Sand		Yes
	Dust		Yes
	Smoke		Yes
	Volcanic Ash		No

Environmental Conditions (Weather)

Attribute	Sub-attribute	Sub-attribute	Capability
Day lux (≥2000lx)	Elevation of the sun above the horizon (as a range in degrees)	-	Yes provided the elevation still provides a lx level of <1
	Position of the sun	In front	Yes
		Behind	Yes
		Right side	Yes
		Left side	Yes

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Cloudiness (oktas)	Clear, sky clear 0-1 oktas	–	Yes
	Partly cloudy	Few clouds 1-2 oktas	Yes
		Scattered clouds 3-4 oktas	Yes
		Broken clouds 5-7 oktas	Yes
	Overcast 8 oktas	–	Yes

Environmental Conditions (Connectivity)

Connectivity	Communication	V2V	No
		V2I	Yes
Positioning	Galileo	–	No
	GLONASS		No
	GPS		No
V2I	Communication	–	Yes
	Positioning		Yes

Dynamic Elements (Traffic)

Density of agents	–		Heavy
Volume of traffic			Heavy
Flow rate			Heavy
Agent type			All
Presence of special vehicles			Yes

Dynamic Elements (Traffic)			
Attribute	**Sub-attribute**	**Sub-attribute**	**Capability**
Route	Pre-defined	-	Yes
Navigational Capacity	Unseen Route		No
	Acceleration	Gear Changes	Yes
	Turning	Speed Adjustments	Yes
		Left turns	Upto 60 degrees
		Right turns	Upto 60 degrees
		Lane switching	Yes
Speed	Maximum	-	40 Km/ph
	Minimum		1 Km/ph
Operating Radius	-		5km of 'base'
Safety Features	Fault reporting	-	Log Files & Signal
	ADS fault reporting		Log Files
	Remote access to vehicle control		Yes
	Manual access to vehicle control (safety driver present)		Yes