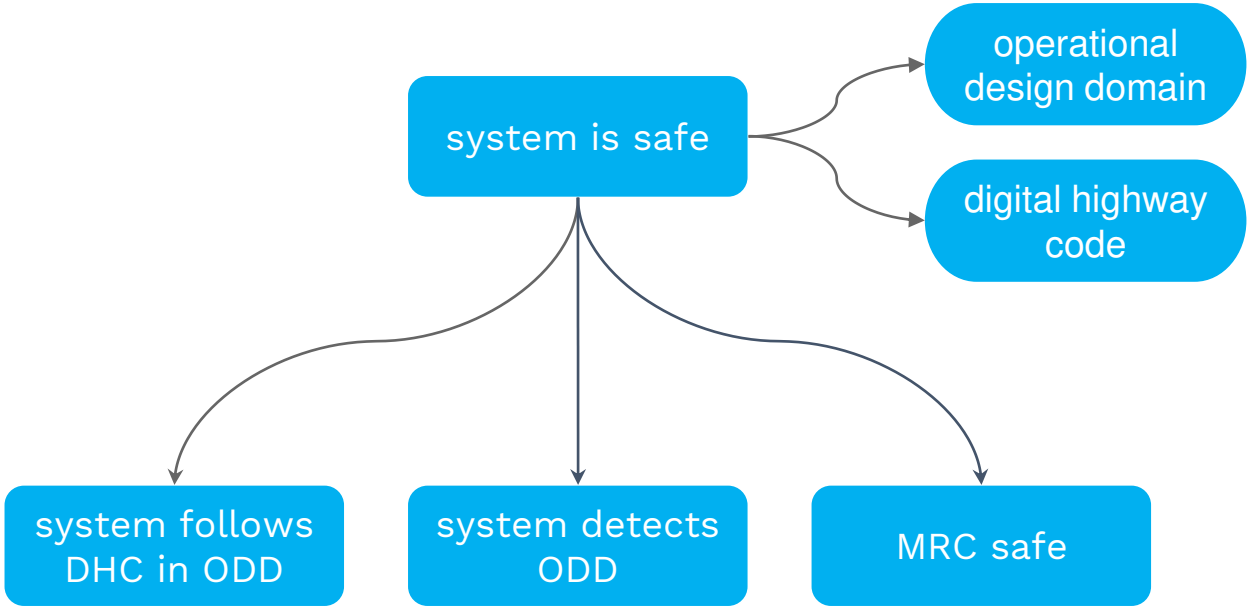
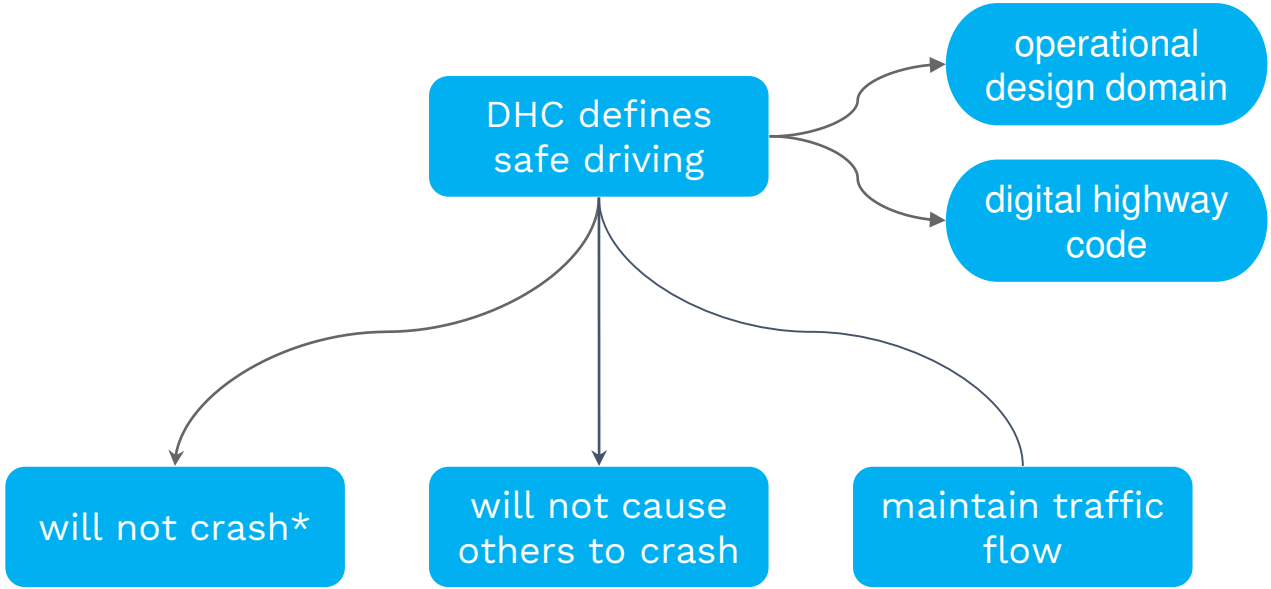
FIVE AI

towards a digital highway code

a (part of the) AV safety argument



but also, DHC defines ‘good’ driving…



*based on a model of other drivers

interesting highway code rules

You should use your lights as required.

When emerging, do not join a road until there is a gap large enough for you to do so safely.

In adverse conditions, take extra care around pedestrians, cyclists, motorcyclists and horse riders.

You should allow access into and from side roads, as blocking these will add to congestion.

Drive carefully and slowly when the pavement is closed due to street repairs and pedestrians are directed to use the road.

In wet/icy ground, drive particularly slowly on bends where loss of control is more likely. Brake progressively on the straight before you reach a bend. Having slowed down, steer smoothly round the bend, avoiding sudden actions.

Only flash your headlights to let other road users know that you are there. Do not flash your headlights to convey any other message or intimidate other road users.

Only overtake on the left if the vehicle in front is signalling to turn right, and there is room to do so.

In fog, You should be able to pull up well within the distance you can see clearly.

Before you set off you MUST ensure that lights are clean and number plates are clearly visible and legible.

In a ‘school area’, drive slowly until you are clear of the area.

The two-second gap should be at least doubled on wet roads and increased still further on icy roads.

When turning right across a line of slow-moving or stationary traffic, look out for cyclists or motorcyclists on the inside of the traffic you are crossing. Be especially careful when turning, and when changing direction or lane.

You must wear a seatbelt in cars where available.

On a dual carriageway , do not overtake on the left or move to a lane on your left to overtake.

Do not overtake with double lines separating the lanes, if there is a solid line on your side of the road. However, you may cross the line if necessary, provided the road is clear, to pass a stationary vehicle, or overtake a pedal cycle, horse or road maintenance vehicle, if they are travelling at 10 mph (16 km/h) or less.

The speed limit is the absolute maximum and does not mean it is safe to drive at that speed irrespective of conditions. You should always reduce your speed when the road layout or condition presents hazards, such as bends, hills, etc.

Highway Code

- Gotchas
  - In wet/icy ground, drive particularly slowly on bends where loss of control is more likely.
  - When turning right across a line of slow-moving or stationary traffic, look out for cyclists or motorcyclists on the inside of the traffic you are crossing.
- Culture
  - Only flash your headlights to let other road users know that you are there. Do not flash your headlights to convey any other message or intimidate other road users.
  - !!
- Traffic flow
  - You should allow access into and from side roads, as blocking these will add to congestion.
  - When emerging, do not join a road until there is a gap large enough for you to do so safely.
- Normative
  - On a dual carriageway , do not overtake on the left or move to a lane on your left to overtake.
  - Do not overtake with double lines separating the lanes, if there is a solid line on your side of the road. However, you may cross the line if necessary, provided the road is clear, to pass a stationary vehicle [...]
- Risk reduction
  - In a ‘school area’, drive slowly until you are clear of the area.
  - The two-second gap should be at least doubled on wet roads and increased still further on icy roads.

Highway Code

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- Culture
  - Only flash your headlights to let other road users know that you are there. Do not flash your headlights to convey any other message or intimidate other road users.
  - ← !!
- Traffic flow
  - You should allow access into and from side roads, as blocking these will add to congestion.
  - When emerging, do not join a road until there is a gap large enough for you to do so **safely.**
  - **tension with risk reduction!**
- Normative
  - On a dual carriageway , do not overtake on the left or move to a lane on your left to overtake.
  - Do not overtake with double lines separating the lanes, if there is a solid line on your side of the road. However, you may cross the line if necessary, provided the road is clear, to pass a stationary vehicle [...]
- Risk reduction
  - In a ‘school area’, drive slowly until you are clear of the area.
  - The two-second gap should be at least doubled on wet roads and increased still further on icy roads.

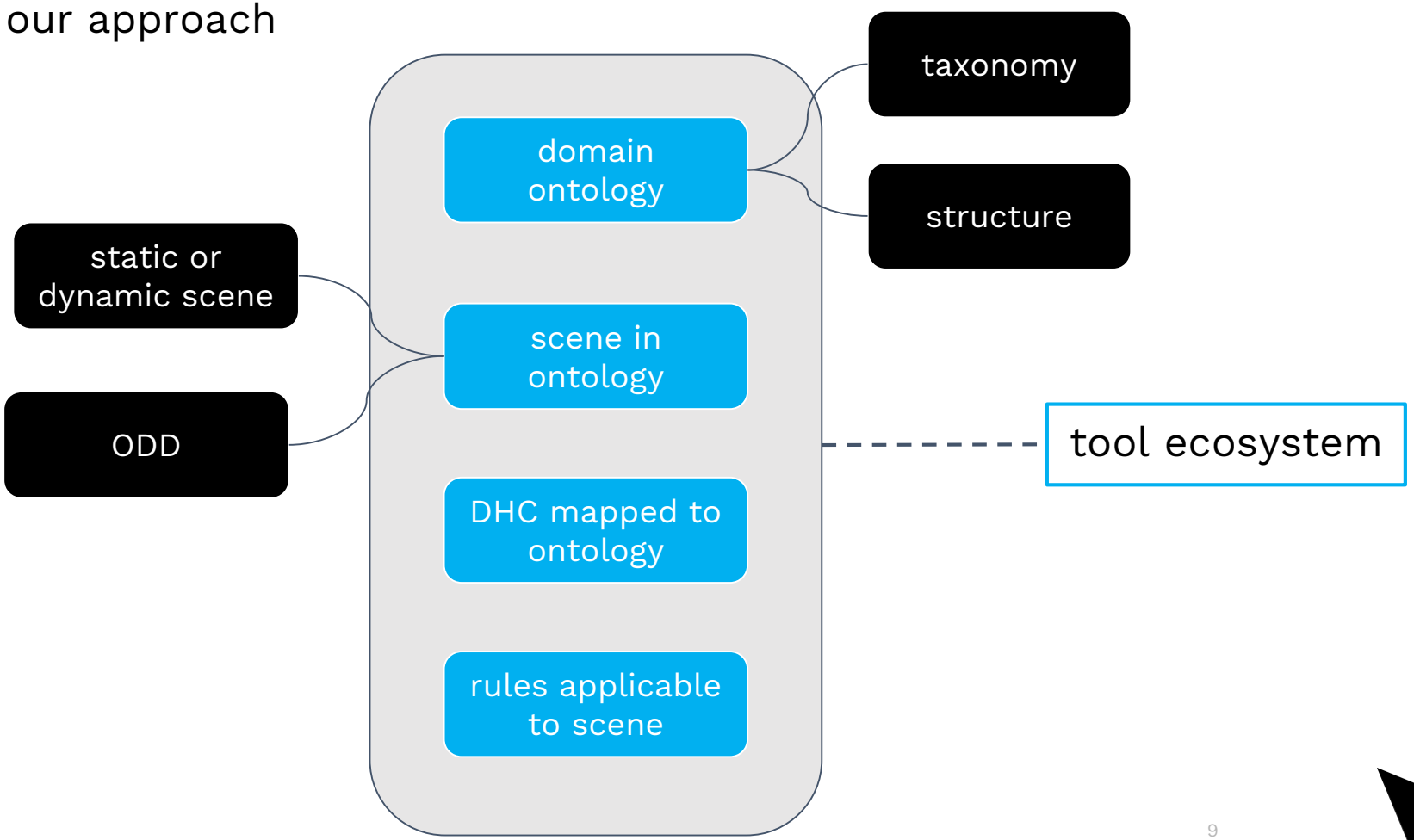
challenge

develop a digital highway code that is formal, but inspectable

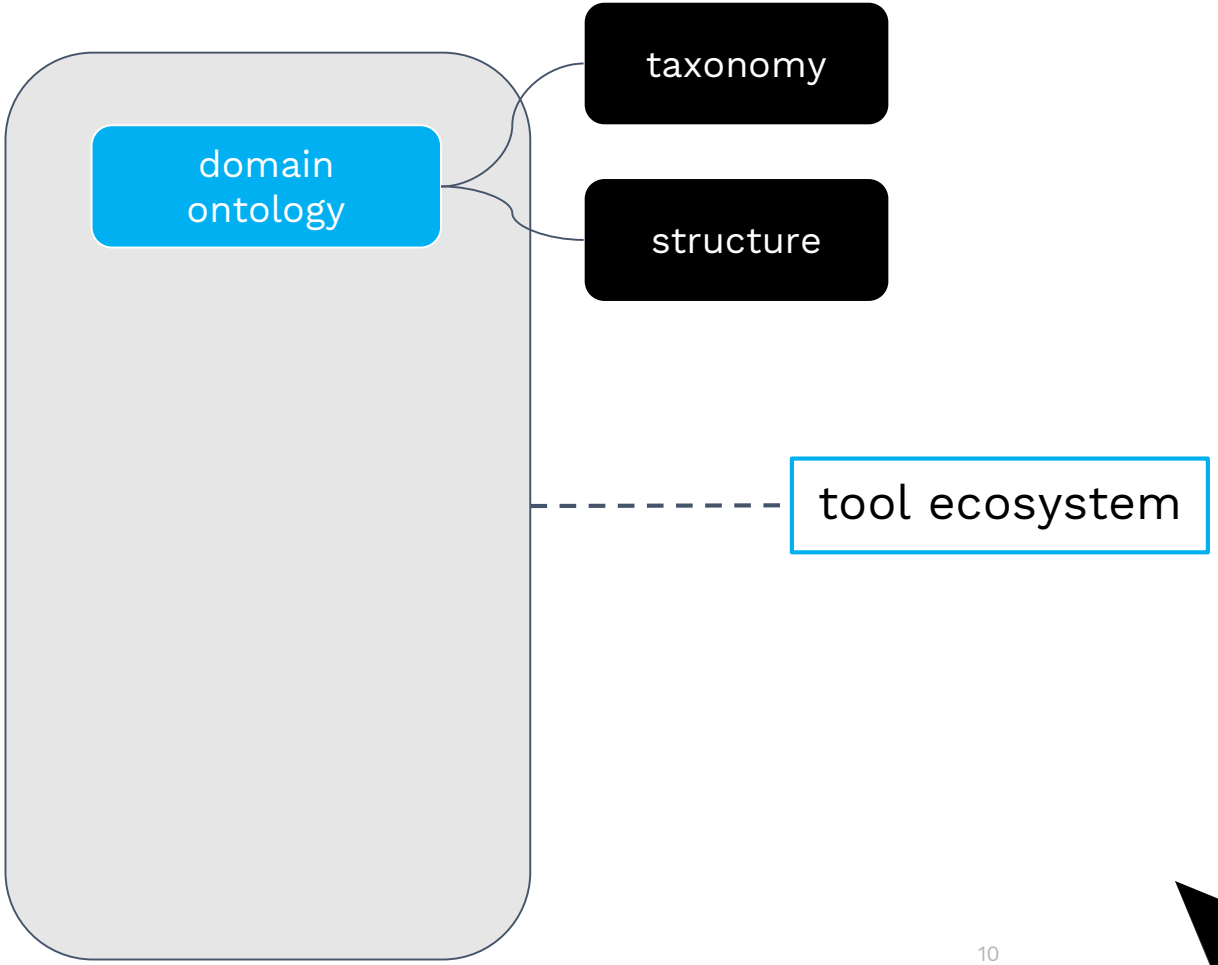
that is broadly consistent with conventional highway code (or convention)

that resolves all ambiguities and clarifies how an AV plans to drive within its ODD

our approach

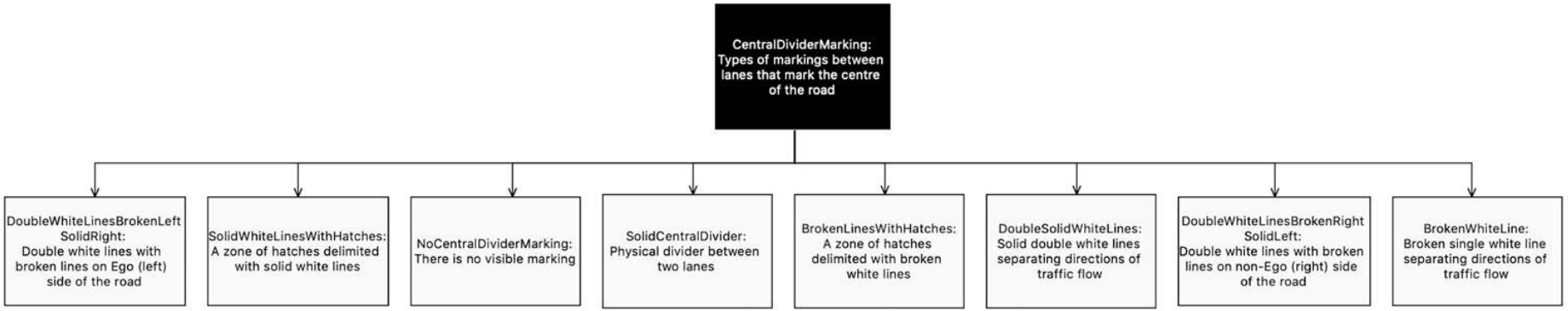


our approach



domain ontology — taxonomy

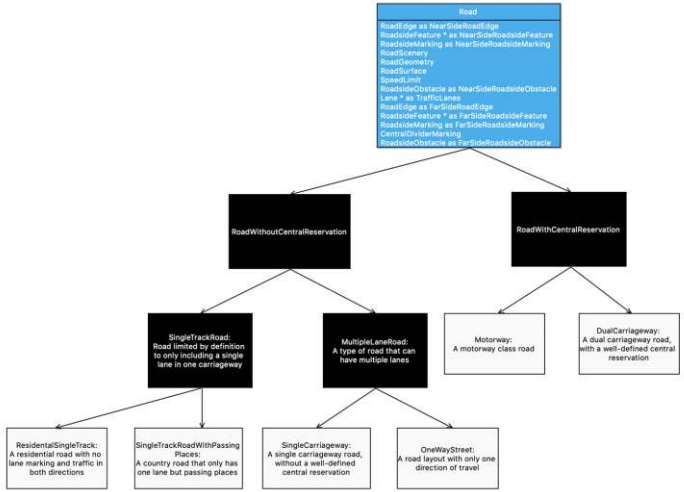
```
CentralDividerMarking : "Types of markings between lanes that mark the centre of the road" {
    atomic BrokenWhiteLineCentralMarking : "Broken single white line separating directions of traffic flow"
    atomic DoubleWhiteLinesBrokenLeftSolidRight : "Double white lines with broken lines on Ego (left) side of the road"
    atomic DoubleWhiteLinesBrokenRightSolidLeft : "Double white lines with broken lines on non-Ego (right) side of the road"
    atomic DoubleSolidWhiteLines : "Solid double white lines separating directions of traffic flow"
    atomic SolidWhiteLinesWithHatches : "A zone of hatches delimited with solid white lines"
    atomic BrokenLinesWithHatches : "A zone of hatches delimited with broken white lines"
    atomic NoCentralDividerMarking : "There is no visible marking"
    atomic SolidCentralDivider : "Physical divider between two lanes"
}
```



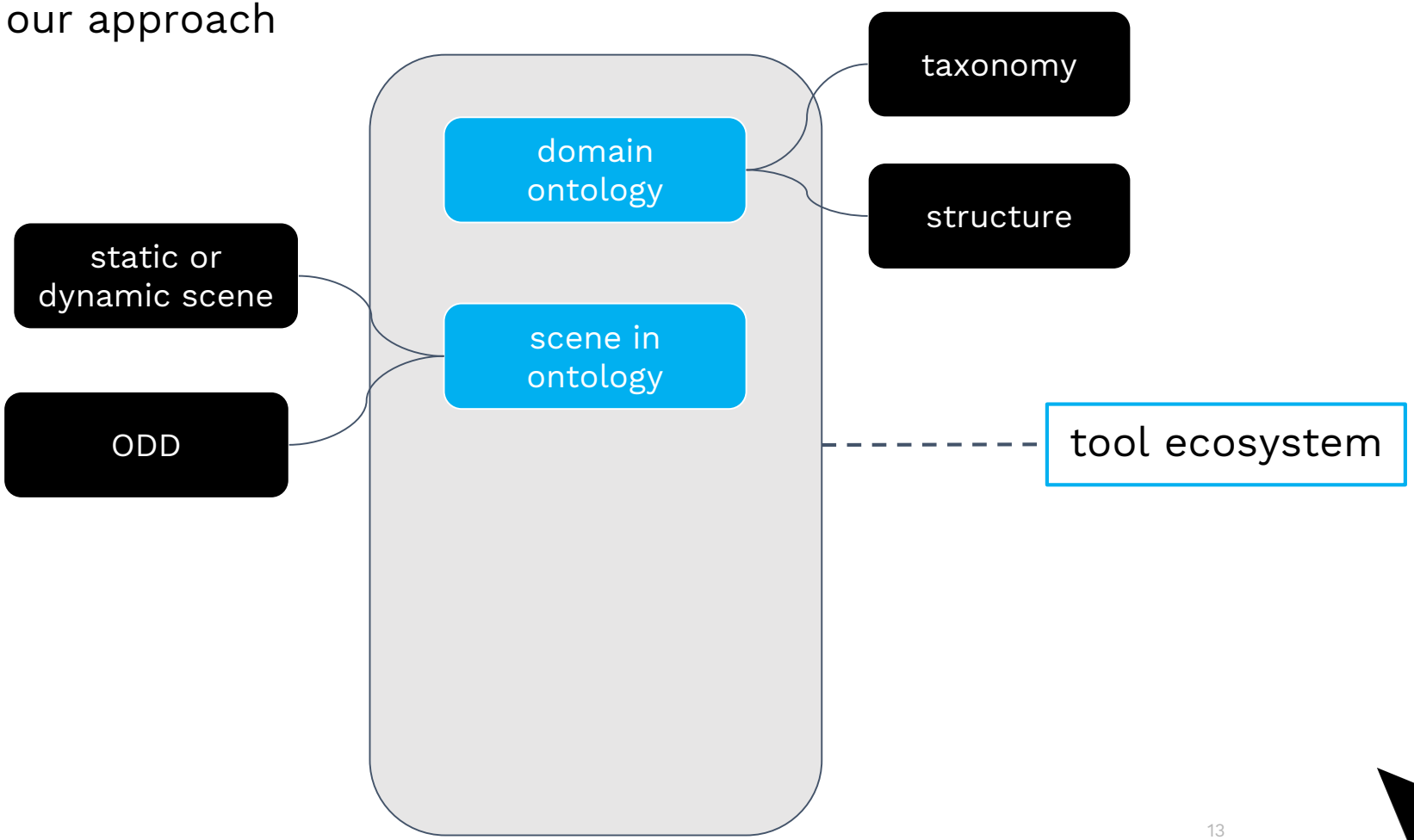
domain ontology

structure

```
Road{
  RoadWithoutCentralReservation{
     SingleTrackRoad : "Road limited by definition to only including a single lane in one carriageway" {
        atomic ResidentalSingleTrack : "A residential road with no lane marking and traffic in both directions"
        atomic SingleTrackRoadWithPassingPlaces : "A country road that only has one lane but passing places"
     }
     MultipleLaneRoad : "A type of road that can have multiple lanes"{
        atomic OneWayStreet : "A road layout with only one direction of travel"
        atomic SingleCarriageway : "A single carriageway road, without a well-defined central reservation"
     }
  }
  RoadWithCentralReservation{
     atomic DualCarriageway : "A dual carriageway road, with a well-defined central reservation"
     atomic Motorway : "A motorway class road"
  }
}
attributes
        optional RoadEdge as NearSideRoadEdge default Curb
        optional RoadsideFeature * as NearSideRoadsideFeature default Pavement
        RoadsideMarking as NearSideRoadsideMarking
        RoadScenery
        RoadGeometry
        RoadSurface default AsphaltSurface
        SpeedLimit
        optional RoadsideObstacle as NearSideRoadsideObstacle
        Lane * as TrafficLanes
        optional RoadEdge as FarSideRoadEdge default Curb
        optional RoadsideFeature * as FarSideRoadsideFeature default Pavement
        RoadsideMarking as FarSideRoadsideMarking
        CentralDividerMarking
        optional RoadsideObstacle as FarSideRoadsideObstacle
```



our approach



scene in ontology

static or dynamic scene

scene in ontology

static scene

```
static scene Example is {
   RoadStructure with  {
      Road is SingleCarriageway with {
         CentralDividerMarking is BrokenWhiteLineCentralMarking,
         NearSideRoadsideFeature is Pavement,
            NearSideRoadEdge is Curb,
            NearSideRoadsideMarking is DoubleRedLine,
            RoadGeometry is StraightRoadGeometry,
            RoadSurface is AsphaltSurface,
            SpeedLimit is Thirty,
            FarSideRoadsideFeature is Pavement,
            FarSideRoadEdge is Curb,
            FarSideRoadsideMarking is DoubleRedLine,
            TrafficLanes are {
               Lane with {
                  LaneNumber is LaneOne,
                  LaneType is IntegratedBikeLane,
                  LaneDirection is EgoDirection
               },
               Lane with {
                  LaneNumber is LaneTwo,
                  LaneType is NormalLaneOfTraffic,
                  LaneDirection is OncomingDirection
               }
            }
      },
      BusStopInLane with {LaneNumber is LaneTwo}
      }
}
```

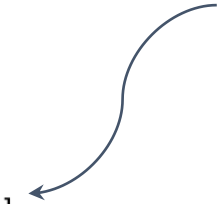
the syntax does need some work :)

scene in ontology

dynamic scene

```
dynamic scene DynamicExample is {
      EnvironmentalState with{
         GroundCondition is WetGround,
         WeatherCondition is ClearCalm,
         AirParticulateMatter is ClearAir,
         Lighting is SunOverhead
      } ,
      SceneEnvironmentState is SuburbanEnvironment,
      ActiveRoadState with {
         GenericTrafficDensity is LowTrafficDensity,
         PertinentSceneElements are Bus, Car, Lorry
      },
      EgoState with {
         FunctionalManeouvre is VehicleDistanceModeration with
            { VehicleBeingFollowed is Car, FollowingVehicleAction is GentleBraking },
         VehicleControlAction is GentleBraking
      },
      RoadStructure with  { ..
      //as before
}
```

scene in ontology — odd



```
dynamic odd {
  for element WeatherCondition we allow [ClearCalm, Windy, LightRain]
  for element GroundCondition we allow [DryGround, WetGround]
  for element AirParticulateMatter we do not allow [SensorParticulate, Fog]
  for element AlteredCondition we do not allow anything //e.g. accident, road works, etc.
  for element RoadDescription we allow [SingleCarriageway, OneWayStreet, DualCarriageway]
  for element SceneEnvironmentState we do not allow [SchoolArea, HomeZone, QuietZone, SharedSpace]
  for element RoadIntersectionFeature we do not allow [StaggeredCrossroads, UnmarkedJunction,
                                        LargeRoundabout, SignalledRoundabout]
  //much more below
```

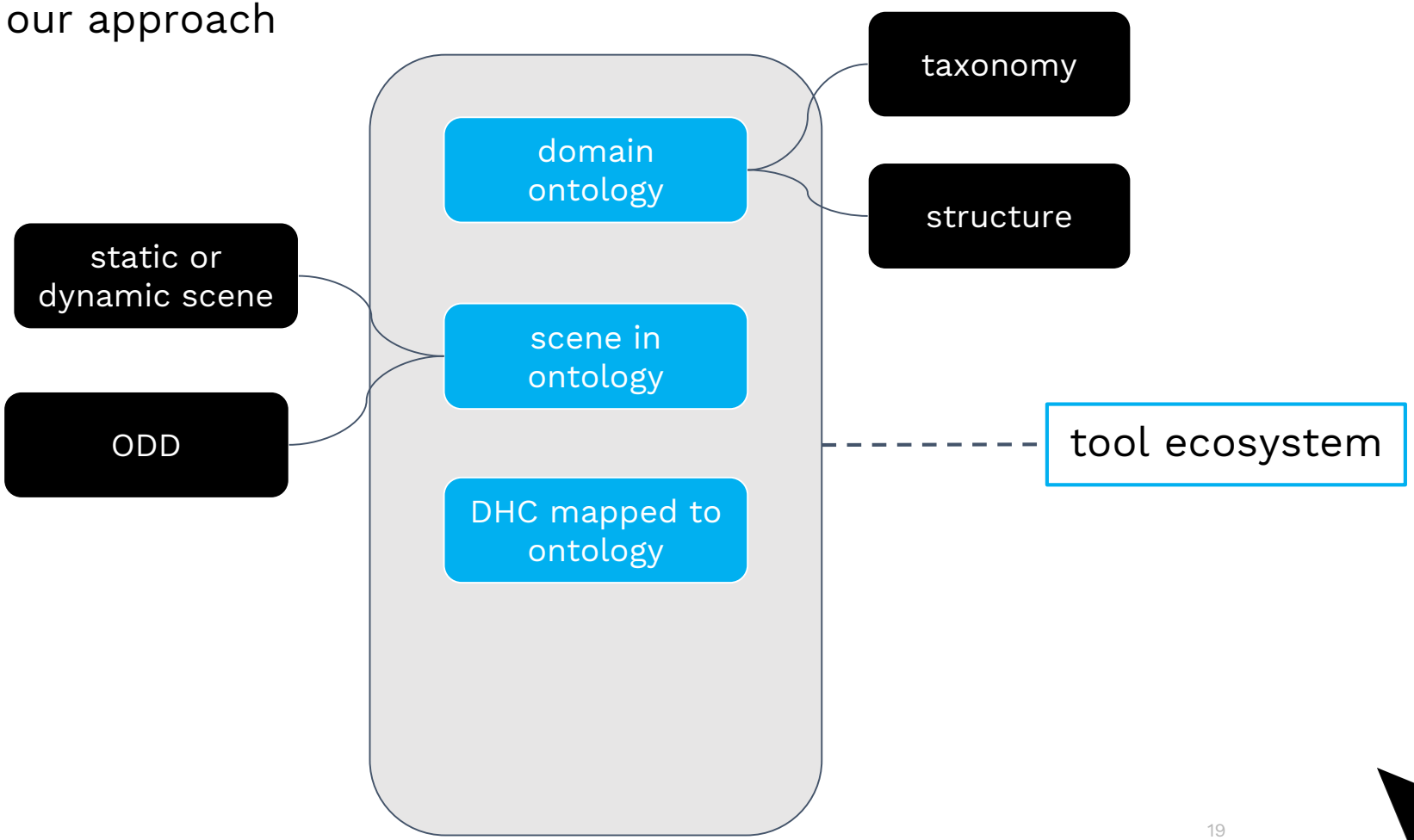
scene in ontology

odd

```
dynamic scene DynamicExample is {
      EnvironmentalState with{
         GroundCondition is WetGround,
         WeatherCondition is ClearCalm,
         AirParticulateMatter is Fog,
         Lighting is SunOverhead
      } ,
      SceneEnvironmentState is SuburbanEnvironment,
      ActiveRoadState with {
         GenericTrafficDensity is LowTrafficDensity,
         PertinentSceneElements are Bus, Car, Lorry
      },
      EgoState with {
         FunctionalManeouvre is VehicleDistanceModeration with
            { VehicleBeingFollowed is Car, FollowingVehicleAction is GentleBraking },
         VehicleControlAction is GentleBraking
      },
      RoadStructure with  { ..
      //as before
}
```

The fog takes this scene outside of the odd

our approach

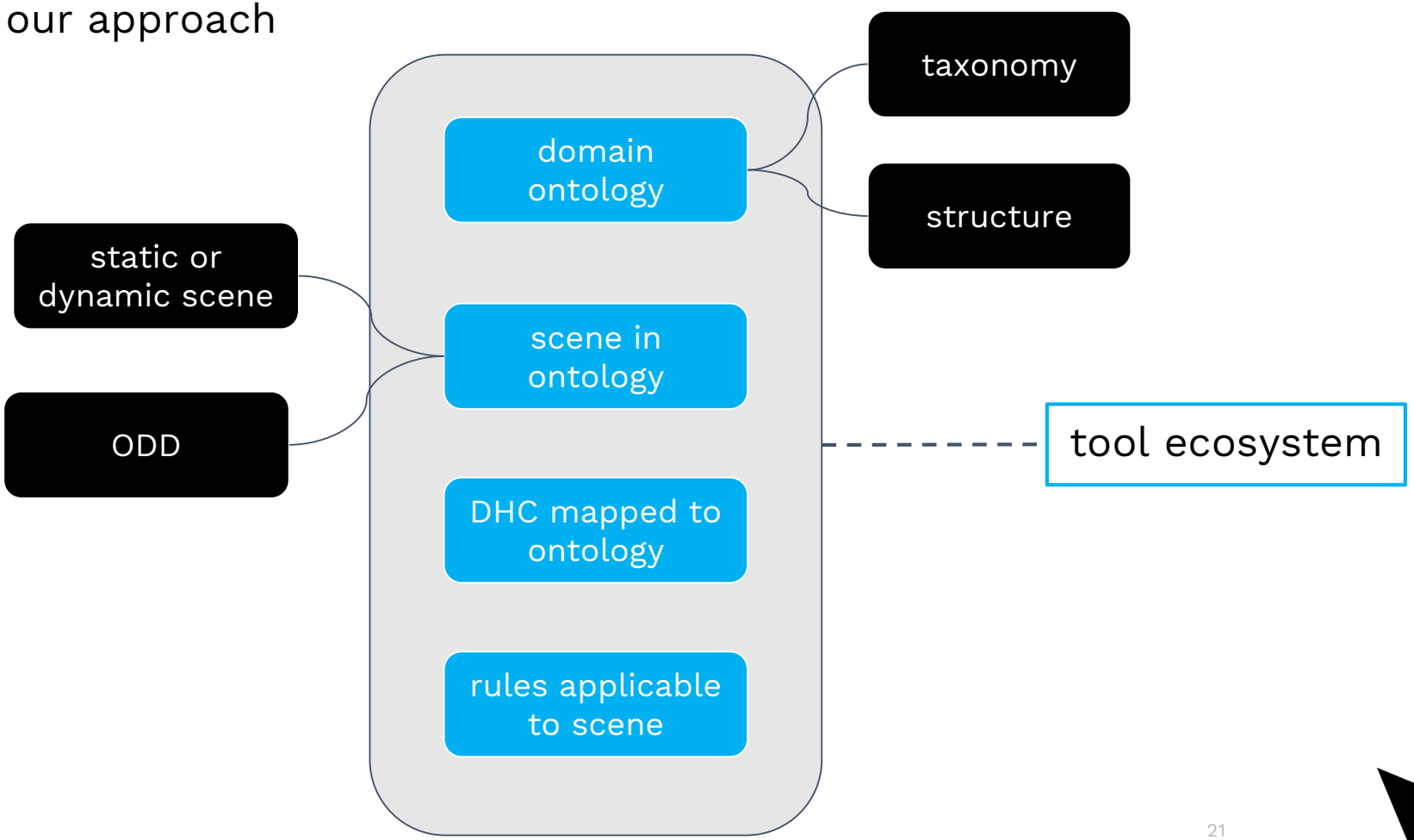


DHC mapped to ontology

```
DrivingInLane : "Generic driving along a lane" {
    atomic LaneFollowing : "Safe lane positioning, moderating speed according to road layout, speed limits and progress."
    atomic VehicleDistanceModeration: "Longitudinal distance and speed moderation from vehicles in the EGO trajectory path"
      attributes Vehicle as VehicleBeingFollowed LongitudinalAction as FollowingVehicleAction
    Associated Rules {
      rule HighwayCodeDistanceModeration: "You should leave enough space between you and the vehicle in front so that you can pull up safely if it suddenly slows down or stops. "
      rule HighwayCodeGap : "You should allow at least a two-second gap between you and the vehicle in front on roads carrying faster-moving traffic and in tunnels where visibility is reduced."
      //...
    }
    atomic VRUDistanceModeration: "Longitudinal distance and speed moderation from VRUs in the EGO trajectory path"
      attributes Objects as TheVRU
      relevant when Pedestrian Bicycle Motorcycle
    Associated Rules {
      rule HighwayCodeVRUModeration: "Always leave a 1.5m+ lateral gap between any VRUs on the road side"
      //...
    }
    atomic BeingOvertakenInLane : "When you are being overtaken"
    attributes
        Vehicle as OvertakingVehicle
    Associated Rules {
      rule : "If a driver is trying to overtake you, maintain a steady course and speed,  slowing down if necessary to let the vehicle pass. "
      rule : "Never obstruct drivers who wish to pass. Speeding up or driving unpredictably while someone is overtaking you is dangerous. "
      rule : "Drop back to maintain a two-second gap if someone overtakes and pulls into the gap in front of you."
    }
  }
  attributes
    optional LaneNumber as EgoLaneFollowingLaneNumber default LaneOne
  Associated Rules {
    rule : "You MUST NOT exceed the maximum speed limits for the road and for your vehicle."
    rule difficultGeometrySpeed : "The speed limit is the absolute maximum and does not mean it is safe to drive at that speed irrespective of conditions. Driving at speeds too fast for
      the road and traffic conditions is dangerous. You should always reduce your speed when the road layout or condition presents hazards, such as bends."
      relevant when HillRoadGeometry CrestRoadGeometry CornerRoadGeometry
  //etc. etc.
```

rules inherited through hierarchy; relevance determines rule in force

our approach



rules applicable to scene

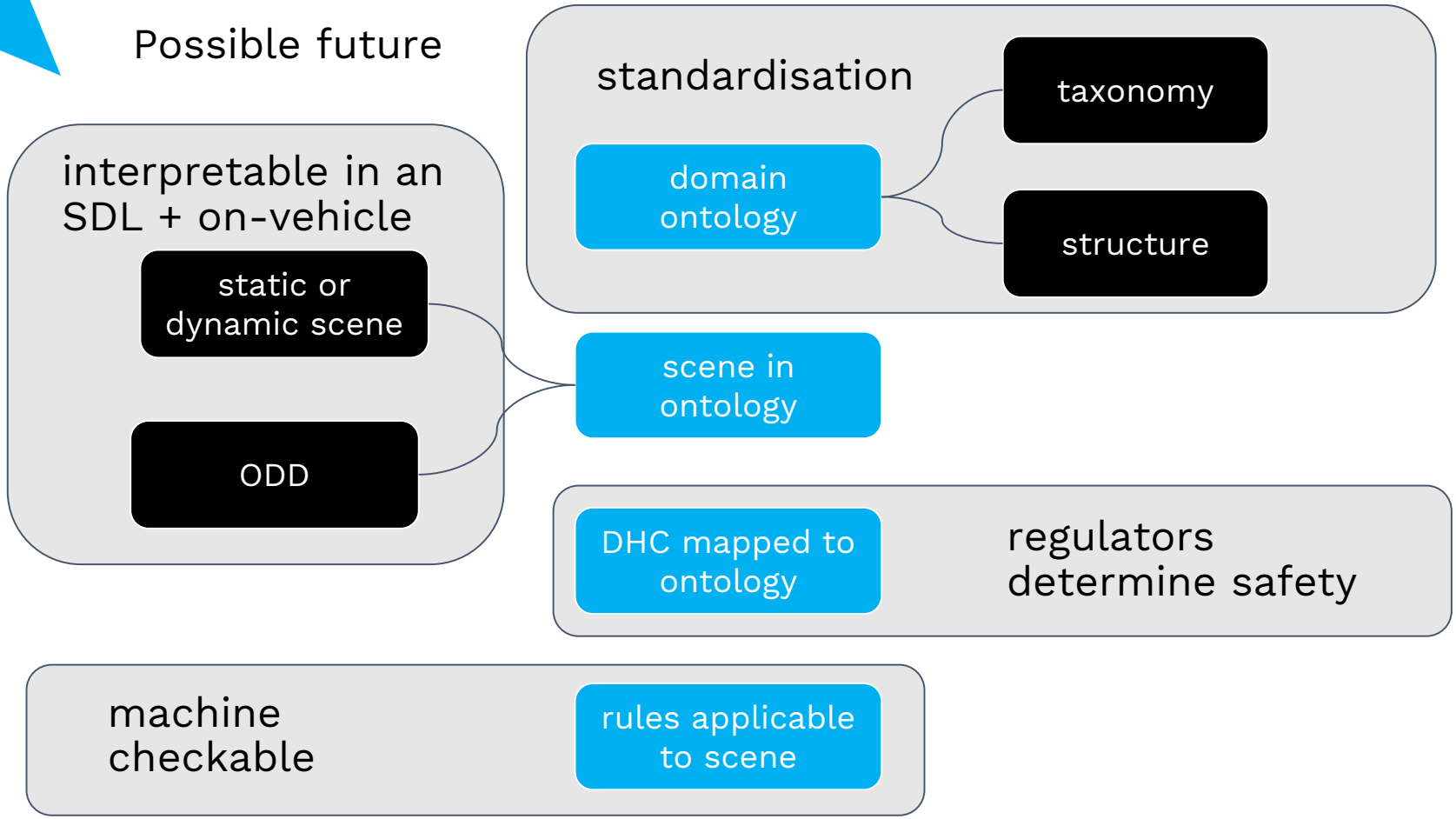
```
static scene firstStreetFromStartToFirstTrafficLight is {
    RoadDescription with  {
        SingleCarriageway with {
```

The Applicable Rules are:

- Where a single carriageway has three lanes and the road markings or signs do not give priority to traffic in either direction; use the middle lane only for overtaking or turning right. Remember, you have no more right to use the middle lane than a driver coming from the opposite direction; do not use the right lane
- Where a single carriageway has four or more lanes, use only the lanes that signs or markings indicate
- Unless road signs or markings indicate otherwise, you should use; left lane when going left; right lane when going right; most appropriate when straight ahead.
- You must not drive dangerously
- you must not drive without care and attention
- you must not drive without reasonable consideration for other road users
- You MUST NOT drive on or over a pavement, footpath or bridleway except to gain lawful access to property, or in the case of an emergency.

```
        }
    }
}
```

Possible future



thanks,
questions?