Management of Electronic Surface Transport Regulations (METR)

Vision

V1.0

DRAFT

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INTERNATIONAL
ITS COOPERATION

Introduction

We live in a transformative time with respect to personal transportation. Developments in automated driving suggest a future inclusive of, if not eventually dominated by vehicles that drive themselves. Adoption of personal transport devices, from e-bikes to motorized scooters, has multiplied the variety of vehicles sharing roadway space. The desire on the part of many urban zones to minimize congestion, provide safe spaces for all inhabitants and maintain viable economics is leading to a variety of challenges in the management of urban spaces including the roads, kerbside[1] and sidewalks. This leads to a plethora of ordinances, regulations and laws that must be communicated to all road users, including vehicle operators and travellers with portable devices, human and machine, as well as entities that manage the roadway and nearby assets.

This is a significant burden to entry for the automated vehicle (AV). Today the AV developer must be responsible for digitizing that information in a form that the automated driving system (ADS) can understand. This means that each developer must codify operating restrictions for any environment in which their vehicle may operate. Given the thousands of jurisdictions that exist in most countries, this quickly becomes a large barrier to deployment and maintenance.

Source: https://www.science-engineering.co.uk

AVs can also use more traditional methods to interpret legal requirements in their surroundings, such as interpreting signage or roadway markings. This is difficult, especially in urban areas with large amounts of overlapping signage. Worse, signs can be contradictory or out of date, requiring the AV to adjudicate in the field; signs can be obstructed, damaged and weathered; or camera and other sensor technology may not be advanced enough to assure required clarity for the automated system. Additionally, and especially for local ordinances, information may be conveyed in a variety of ways even within a given country. Given the current state of practice, every AV developer must develop mechanisms for learning of and determining how to follow laws and rules across thousands of jurisdictions.

What if Intelligent Transportation Systems (ITS) could help fill this need? What if vehicle operational regulations were digitized by their creators (or a surrogate), and provided to ITS users (e.g., vehicle operators, travellers, and the systems that they use) though a well-defined, publicly available interface? Management of Electronic Surface Transport Regulations (METR) will provide a means for ITS user systems to obtain *machine-interpretable, publicly-available, transport-related, authoritative information for the use of surface transport facilities to better provide safe, efficient, sustainable, comfortable, and equitable transport services.* .

[1] As an ISO standards effort, the METR documentation is written using British English.

Vision

METR will facilitate an overall approach and the mechanisms for the distribution of road rules, where the consumers of these rules can be assured of the authenticity of the regulation or ordinance. This notion of authenticity is the critical point: if road rules are to be used to guide the operations of vehicles on roadways, the users of those rules must have confidence in the veracity of those rules. There must be a mechanism whereby the receiver of the rule can verify that the rule is correct and legitimate.

Source: pixabay.com

METR as a concept applies to the entire life cycle of a traffic regulation beginning immediately after that regulation is codified, and includes the complete distribution chain of the regulation, from the point when the regulation is created, to when it is disseminated and shared with end user devices. As such, it may incorporate or define data models, distribution mechanisms, cryptographic processes, implementer roles and responsibilities and any other item or concept that is required to distribute machine-usable road regulations to users. METR's implementations will have to respect variances in scope, operations, end-user distribution mechanisms and other constraints among its participants.

Source: https://wikimedia.org

One of the key goals of METR is to facilitate the integration of Automated Vehicle (AV) technology with the users and operators of the transportation system. It is clear that AV is emerging in our transportation systems, and it is also clear that transportation operators are struggling to understand what that means for them, don't want to be surprised, and would support AV *if* they didn't have to undertake massive investments. Connected vehicle technologies that rely on market forces are relatively common; however, those that rely on cooperation between government and the telematics providers have not been widely deployed. Facilitating AV should acknowledge the role that transportation providers can take, but not depend on any new substantial investments by any party that cannot clearly identify the benefits and thus would struggle to invest and deploy.

One area the standards community may help is in bridging the gap between AV developers and the myriad of agencies that establish the operating rules for vehicles by working with experts to create and then standardize METR processes. Providing this bridge, with the notable constraint of not requiring significant investment from either party, could facilitate AV operations, better enable transportation operators to understand the impact of AV on their limited roadway resources, and provide secondary benefits to existing (human) drivers.

What Is It?

METR will define machine-interpretable formats for rules-of-the-road, and mechanisms for rule exchange and requirements relevant to authentication, including update, maintenance, and storage. Rules-of-the-road are those regulations related to surface transportation; they include context for their regulation: time, location, and applicability. Since what constitutes a road (including sidewalks and other pathways used by travellers and vehicles), or to whom a regulation applies can vary between jurisdictions, these rules must be transformed from their current signage/legal form to a common encoding form that machines can interpret relative to the machine's context.

Regulations can be imparted by agencies at many levels (e.g., federal, state, county, municipal, etc.), and typically are enforced by local agencies that are distinct from the agency that creates the regulation. A human traveller gains knowledge of such regulations through education (drivers' education, licensing), local ad-hoc knowledge passed on by others, and through interpretation of signage or markings. In particular, local ordinances are nearly always communicated by interpretation of signage and markings. An automated vehicle must somehow learn this same information; either programmed in by the AV developer or learned dynamically by observing the environment (e.g., by interpreting the same signs that humans use today). This can be a challenge, as signage and markings can be contradictory, can be difficult to read due to fading or wear and tear, and can be obscured by weather, lighting, other vehicles, or pedestrians. Signs come in many sizes and follow many standards; in some cases, they do not even follow standards and so they can be challenging to interpret. Sign position might also vary, especially around work zones.

Source: Jonathan Booth

Some jurisdictions may never centrally publish their regulations; such publication takes time and effort, and absent incentive or a law requiring it, a jurisdiction may choose not to publish in a way that would be useful to this effort. Thus, METR must consider mechanisms for intermediaries to learn of and publish regulations by proxy; authentication thus becomes a challenge, as the source of regulation in the digital world is not the source of the regulation in the physical world.

Source: Jonathan Booth

To get to a place where METR becomes the norm, we will have to develop awareness on the part of the rule-maker, establish consistent data governance and management processes, cybersecurity best practices, and dissemination methods. This will take many years.

Driving Factors

The initial factor driving METR is the desire to remove a barrier to AV deployment and operations. While most obviously applicable to the car-sized AV, this should also include regulations relevant to automated freight transport of all sizes. Early pilots and small-scale deployments focusing on last mile consumer delivery are occurring now, and related regulations vary between sites and need to be communicated to other users so they may understand what to expect (e.g., deployment of sidewalk-using delivery robots in Pennsylvania allows operations up to 12 mph, in Florida 15 mph; classification in PA allows 550 pound bots, while Washington allows only 120 lbs.; speeds and sizes that may be surprising to other sidewalk users).

Secondarily however, METR may facilitate other activities gaining traction in the ITS space, such as: work zone management, dynamic zone operations, kerbside management, parking management. Further, the development and use of many new vehicle types and desire for more pedestrian-friendly cities suggest that vulnerable road users (VRU) receive more attention and protection, particularly in urban environments, and that such protection may include regulations relevant to VRUs and other vehicles that VRUs may interact with.

Benefits and Consequences

A key benefit of METR deployment is facilitation of AV deployment. This may provide some feedback into regulatory process, enabling some more consistent, and possibly easier to reconcile, regulatory structures.

Since it is expected that a METR deployment will require well-defined processes for data management, data governance, cybersecurity, authorization and authentication management, it is likely that these processes will provide input to related processes in transportation operations and possibly enforcement and regulatory processes.

Perhaps of greater value, we can speculate that once a system exists whereby users can receive machine-interpretable regulations, new opportunities will emerge: road operators should be able to dynamically implement zone operations, enforcement regimes may leverage digitized regulations to adopt more automated enforcement techniques; the use of limited access resources may be more dynamically and flexibly controlled—in addition to lane usage, consider sidewalks, loading zones, parking spaces and crosswalks. In addition to the above benefits, METR may enable some new activities:

- Depending on the level of performance and regulations surrounding connectivity, operators may be able to establish legally enforceable restriction zones dynamically in response to, for instance, emergencies, evacuations, or weather-related conditions among others.
- Automated enforcement technologies may also be able to leverage METR data to provide a more homogenous enforcement regime.
- In cooperation with platooned vehicles, operators may be able to establish temporary but specific lane usages around certain types of freight (i.e., hazardous materials) or size of vehicles (i.e., overweight containers).

Strategy

To fulfil its promise, METR will have to fit into the ITS ecosystem in such a way as to satisfy the burgeoning demands of information exchanges related to regulations. There are many users of such regulations, and many situations that should be supported. What follows is a sampling of the scenarios METR is likely to support.

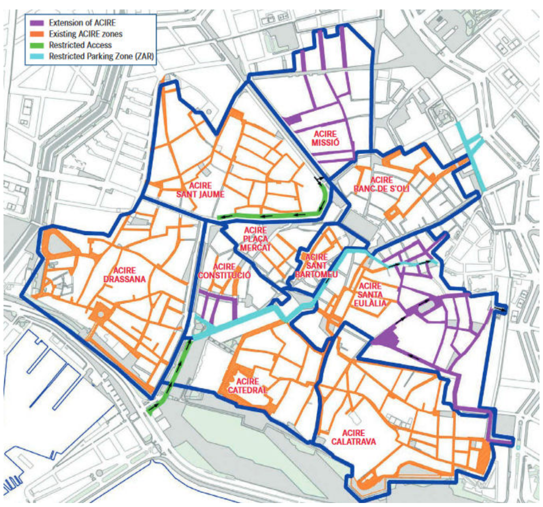
Use Cases

Source: https:// wikimedia.org

A *road vehicle* (personal or freight) will require the regulations for the areas in which it is intending to travel. If it knows its destination this is reasonably predictable; such a vehicle will want all of the regulations on its potential routes that might affect its behaviour. For example, if traveling on a road leading toward a municipality it will want to receive information about ordinances applicable to that vehicle while inside the borders of the municipality. If the vehicle is merely heading that way, or passing through, then it probably needs road qualifications (what types of vehicles are permitted on what roads/lanes), allowable movements, acceptable means of propulsion or emissions, intended purpose, levels of occupancy, speeds, zone control information or other information that may impact the vehicle's potential routing. If the vehicle's path includes potential stops in the municipal region, then it may also need information related to loading zones, parking and vehicle loitering.

Source: https://www.flickr.com

A freight delivery micro-vehicle (aka delivery-bot) will have a destination as the terminus of its path. It will need to receive all relevant regulation information for its potential paths. If the micro-vehicle path is established by a central control facility, then that facility would need the information, though the micro-vehicle would probably still need a subset of that, though it could receive it from its control facility. Regardless, information this vehicle needs will describe the lanes, roads, crosswalks and sidewalks the micro-vehicle is permitted to use, the speeds it is permitted to operate and similar relevant regulatory information.



Source: https://www.palma.cat

From the rule-maker's perspective, zonal management is a primary concern. Many urban operators today are establishing zonal operations, where certain types of vehicles are prohibited or restricted at all or some times of day. These zones can be irregular, can overlap, and can be established or modified in response to a variety of factors such as congestion, air quality or pedestrian safety. Zone characteristics will be established by an agency with authority to create them, that information then disseminated to all vehicles and travellers in and around the area, and also provided to travellers and vehicles headed toward that area.

Closely related to zonal operations, there are behaviours that are permitted in some areas and not others that would need to be disseminated to the types of end users that are affected. For instance, engine braking by commercial vehicles is typically restricted in commercial areas; loitering or loading may be restricted to certain kinds of vehicles, etc.

Various personal conveyances may also be impacted and would benefit by receiving regulation information; this would obviously be in-scope for automated personal conveyances, but more than other types of transport, non-automated personal transports may be restricted from use in particular areas and so may be early beneficiaries of METR data distribution.

Processes

Various processes can be inferred from the typical uses described above. There will need to be two main processes defined to implement METR. Processes by which:

- a regulation or law is put into a machine-interpretable format
- a machine-interpretable regulation is provided to a vehicle, traveller device or any other end user as trusted, verifiable messages.

There will be many derivative and related processes that support those two main processes—creation and delivery.

- Creation: Various mechanisms will likely be established for the transformation of an artifact of law or regulation into a machine-interpretable format, from various actors. There may be mechanisms by which regulators provide this directly, there will be mechanisms to support a third party's production of this encoded information, and thus there must be a mechanism for the originator of the regulation to audit and verify that the stored regulation correctly interprets the law.
- Delivery: There will be various means for getting METR data to end users, some probably based on subscriptions, and some based on a prompt (query, request etc.) from the end user. To ensure that regulations are authentic and correct, processes for ensuring the integrity and authenticity of regulations at the end user will also have to be created; these will likely require external support, as cryptographic operations may impact both human and machine processes.

Roles and Responsibilities

Who has the authority to create and operate METR systems? Notionally, we can envision many roles in this environment:

The *regulator* creates regulations that affect traffic movements and uses of the roadway. The regulator's scope is typically based on its position with regard to governmental structures, i.e., there could be a federal regulator that creates laws that apply to an entire country, a provincial regulator that creates laws or regulations that apply to a state, region or province, a municipal regulator that creates laws or ordinances relevant to a city or town, and even a campus regulator that creates policy for a private (but publicly-used) facility. There could be multiple relevant entities for any given area, as scopes may overlap, and the number of levels may vary.

The *translator* acquires knowledge of these regulations and puts them into a form that is useful for distribution. What exactly that form is will depend on an analysis of the target users, but we can assume for now at least that this form must lend itself to machine readability and interpretation. Presumably any form that can be made useful for a machine user can also be made useful for a human user.

The *disseminator* provides means for other users to acquire machine-interpretable regulations. There may be multiple levels of such disseminators, some of which may use other, possibly proprietary, information dissemination mechanisms, depending on the business structure of the locale in question.

End users are vehicles, travellers or other surface transport users (e.g., shippers) with portable devices, which need transport information to understand the rules with which they must comply. Automated vehicles need this information to perform the driving task legally, but human-operated vehicles may benefit as well, as the vehicle can provide guidance to the driver based on local regulations. Travelers using other forms of conveyance, such as walking, scooters, wheelchairs, cycles and anything else used to move a person through the transportation network may also acquire and use this information in similar fashion as vehicles (though obviously with varying concerns related to where they operate, speeds and vulnerabilities). Road workers may use this to aid in managing work zones. In some regions enforcement systems might use this information to enhance safety and efficiency through traditional or automated means.

These relative roles, and the paths that regulations follow, are notionally illustrated in Figure 1. Note that the translation/encoding, collection, and dissemination of regulations can be performed at whatever scope is appropriate to the jurisdictions in question. It might be performed nationally, or regionally, or on a state-wide or even municipal-area basis. It should also be clear that METR has no functions related to the actual creation of regulations.

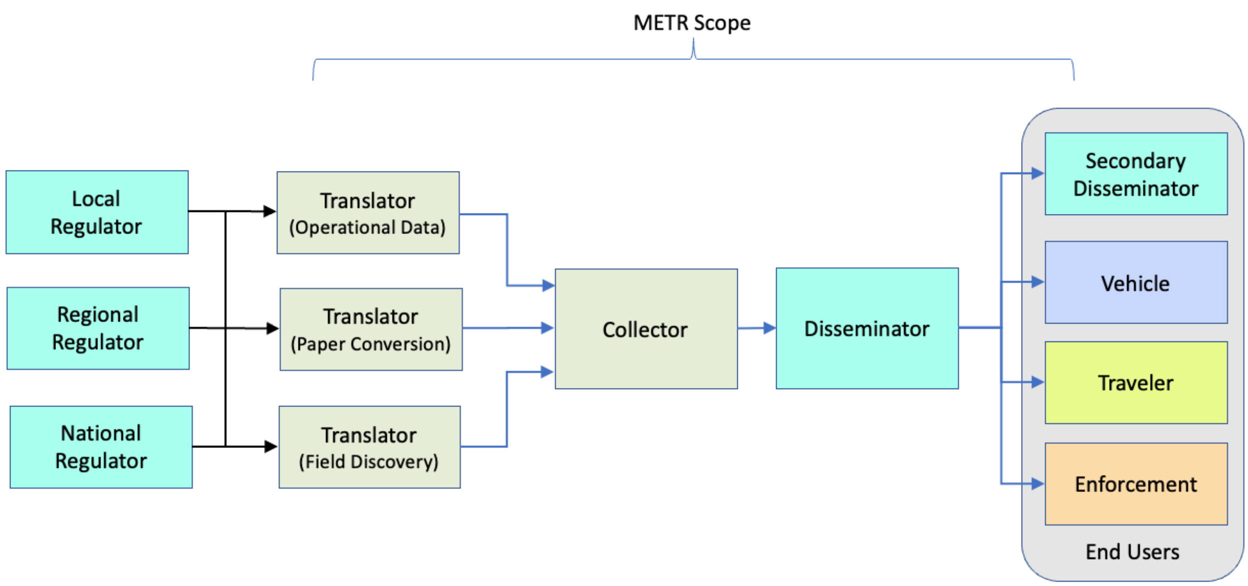


Figure 1: METR Roles

Roadmap

What is the roadmap for achieving this vision? Where are we today, what is required to get us to this vision, and what do intermediate steps look like?

Referencing the roles and exchanges noted above, METR's scope must include all of the information definitions, exchanges, and definition of authentication processes, and may include requirements on intermediary operations, at least those necessary to address concerns related to authentication and privacy. It should not impose any requirements on any participant that are not directly related to the exchange of regulation-related information

While there are some existing materials and relevant projects that might intersect with METR, this is by and large a greenfield or new system. As such, its development will start with a needs analysis and collection of stakeholder concerns. This effort will include the implementation of traceable exercises that ensure stakeholder concerns are addressed and that technology decisions are made as late in the development process as practical. Note that this is not intended to conflict with any ongoing efforts, and in fact may leverage and/or provide useful input to existing projects.

While it is tempting to begin by modelling road regulations and developing a related data model, doing so prior to a reasonable sampling of stakeholder needs runs the risk of developing material that will have to be revised, and so should be delayed until the needs analysis is complete. Consequently, we will follow a more formal systems engineering process to determine stakeholder needs, system requirements, architecture and then produce design materials.

The METR project development team will develop materials that define these artifacts and maintain traceability. The first product to be developed is the Operational Concept (ConOps) that defines stakeholders, roles, needs and conceptualizes potential approaches and benefits. The ConOps builds on the vision described in this document, but defines referenceable, foundational artifacts that trace through the remainder of the systems engineering process. ConOps development will require significant interaction with stakeholders, and so is expected to be the most time consuming of all METR-related document development processes.

Subsequent documents—requirements, system architecture and one or more interface specifications/data dictionaries will define material sufficient to meet those stakeholder needs. Assuming a start in January 2021, we may achieve completion by the end of 2024.

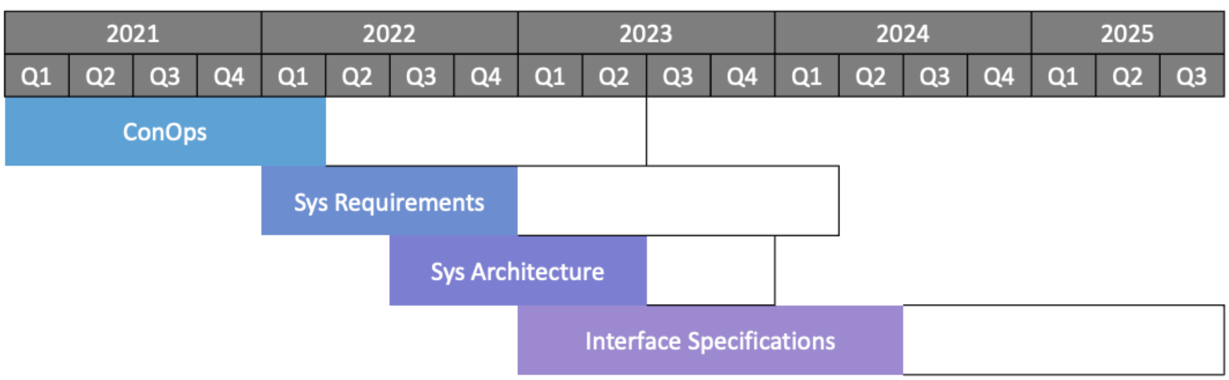


Figure 2: Notional Schedule

The ConOps will be developed by a project team sanctioned through ISO TC204 Working Group 19. The structure of the document will follow ISO 29148. The foundational artifacts defined in this document, primarily stakeholder needs (high-level customer requirements) will be developed based on a series of analysis and outreach sessions to stakeholders. The exact mechanisms will likely include a mix of in-person and web-based sessions so as to enable the greatest breadth of outreach practical given the constraints of time, budget and overriding concerns such as the COVID-19 pandemic.

Subsequent documents will follow well-defined structures—the system architecture will follow ISO/IEC/IEEE 42010 recommendations on architecture, and interface specifications will follow well-worn examples from ISO, ETSI and SAE. The exact format, timing, mechanisms for development of those documents will be defined when the ConOps team has completed a first draft. The number of interface specifications will not be defined until the system architecture has completed a first draft.

While the current focus is on the development of systems engineering documents, in so doing we must also consider factors related to implementation, deployment and operations. Functionality, organizational impacts, changes in technology, concerns related to information access and management, and cultural factors can impact or be impacted by this transformation from today's environment to a future where road rules are disseminated automatically. Figure 3 illustrates a transformation roadmap, providing a high-level aggregation of several snapshots in time from now until a state when we authentic rules-of-the-road might be automatically disseminated. (this roadmap is best understood by reading from the bottom-left to the top-right).

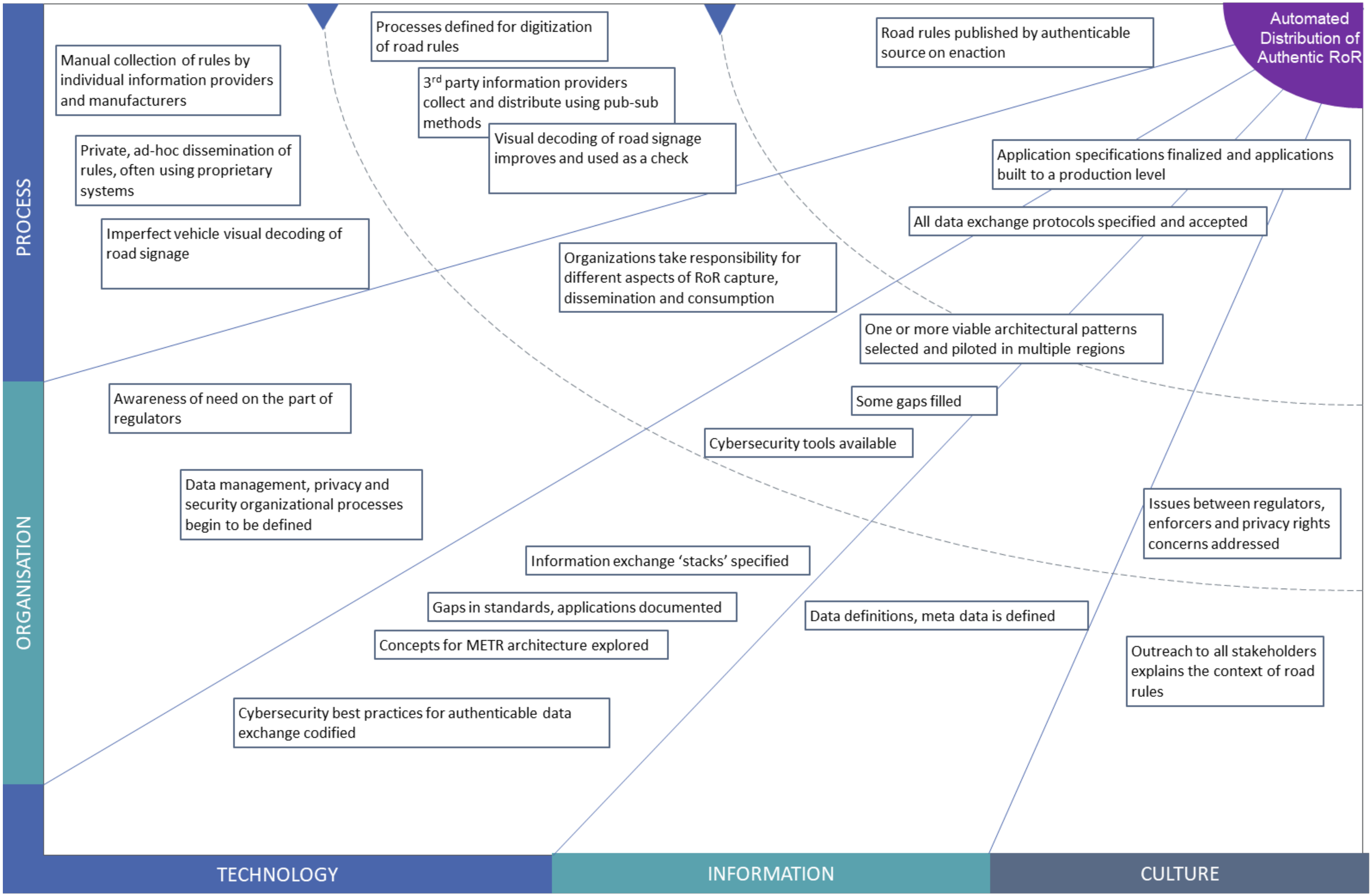


Figure 3: METR Transformation Roadmap

Appendix: User Scenarios

This annex provides notional user scenarios that will be further developed and refined during the development of the ConOps.

Klaus the Truck Operator

Klaus drives a container-carrying commercial vehicle that includes a level 4 ADS. The operational design domain (ODD) for the truck includes most motorways and dual carriageways, but few single carriageways. Thus, the ADS controls the truck over long haul (inter-urban) routes, but Klaus typically takes over once the truck leaves the inter-urban facility. The ADS is updated with operational regulation information for several viable pre-selected routes at the time of load assignment. This occurs by query: electronics on board the truck compute the route to maximize the amount of time spent with the ADS engaged, and then ask for and receive regulation information from the National Machine Regulation Access Point (NMRAP) using METR protocols. The scope of regulations requested cover the entire scope of several viable routes, including the ADS-controlled parts as well as the sections Klaus drives.

When the ADS is in control, it avoids breaking any regulations or ordinances, deviating its route as necessary to avoid doing so (possibly returning control to Klaus as a result). If it detects options, it may prompt Klaus for input, providing him with alternatives such as a longer fully automated route vs. a shorter route that has sections where Klaus must drive.

When Klaus is in control, an in-vehicle display shares relevant regulatory information when Klaus is near an area where a regulation might apply. It automatically notifies him if he seems headed for a road where his truck is not permitted, warns him of speed and lane restrictions and violations automatically. If Klaus deviates from a predicted route, the on-board electronics ask for any new relevant regulations from the NMRAP.

Over time, the on-board electronics build up a sizeable store of relevant regulatory information; regulations are updated by request and only if the regulation is not already stored in the truck's local database, or if the authentication period of the regulation will pass during the point of the trip (e.g., if a regulation's signature depends on a certificate that expires during the trip).

Sandy the Soccer Mom

Sandy the mother of four is the proud owner of an AFV-3000 (AFV=Automated Family Conveyance). She works part time from home; she spends most of her in-vehicle time shuttling children between appointments and events and running errands. The AVF-3000 is optimized for operations in suburbs like hers. It includes a level 4 ADS capable of operating on all roads in the area, in all but the most severe weather conditions. Since it cannot handle true extremes, it does include control hardware so that Sandy can take charge.

Local ordinances in Sandy's locale specify that ADS are not permitted to operate when snow is falling (potentially due to an incident from years prior where several ADS behaved erratically during a snowstorm). When snowfall is expected, the local transportation operator issues an ADS-ban for the areas that expect snow. The operator then watches local radar and uses remote video surveillance to identify any new snowy locations. He also marks those locations as 'ADS-banned' due to the snow. He monitors the developing situation as needed according to locally established policies. The 'ADS ban' status is uploaded to the NMRAP, where it is automatically associated with the appropriate roads and all

AVs in the area are notified of the change in state. Any AV in the area avoids routes that take them through an area where the 'ADS-ban' is in effect.

If Sandy is in the car when an ADS-ban is instituted, she will see and hear an alert, as the AFV-3000 finds a safe transition point (likely a stop or parking spot) for Sandy to take control. If Sandy attempts to start a journey with ADS-ban in effect, the AV will not engage, and Sandy will have to take over the driving task (note this does not affect other safety systems such as automated emergency braking).

Sandy's AFV-3000 maintains a subscription to local regulations so that any changes can be quickly communicated, and links these to Sandy's smartwatch. This way Sandy always knows is she needs to drive or reschedule an appointment.

Bilo the Jet-Set

Bilo doesn't own a car. He doesn't even have a driver's license. He lives in a modern European city with easy access to a variety of public transportation methods that enable him to get wherever he needs. He does, however, travel a fair bit, and when going abroad is sometimes in a locale that is difficult to get around without a car. Thus, Bilo rents a car, typically a high-functioning level 4-equipped model with a fixed ODD that can operate in nearly all conditions on nearly all roads in the area.

This rental AV is maintained by the rental agency and has no controls for a driver to take over. It is programmed to stay in its ODD, maintains a communications link to the rental agency at all times through which safety, mobility and other control commands are received. The agency is subscribed to the NMRAP and forwards to its vehicles those regulations and dynamic ordinances, zones and such, that are appropriate for each vehicle. The rental centre verifies the authenticity of all ordinances. Bilo sees none of this, and only knows that his rental car gets him where he needs to go and presumably does so in a safe and legal manner.

Partially Blind Fiona

Fiona just bought a new cup and saucer and is headed home from the store. Due to a recent eye injury, she relies heavily on ride-sourced services that she accesses through her smartphone. When she requests service, she enters her origin and destination, and the ride-sourced service determines whether to send a driverless or conventional (driver-provided) car based on current demands and the regulations that currently apply. The ride-sourced service also notes that her account is authorized for using special kerbside pickup areas for those with disabilities.

Her smartphone app guides her to the special kerbside pickup area, which happens to also serve as a bus stop. While Fiona is making her way to the pickup area, the ride-sourced service directs a vehicle to meet her. As her ride-sourced vehicle arrives, she is notified; but unfortunately, a bus is currently occupying the space. Since there is no convenient space to pull aside, the vehicle circles the block and informs Fiona of the situation. After one loop, the bus has departed, the driverless vehicle pulls into the bay and Fiona boards.

Rosie the Delivery Robot

Rosie, along with eleven other sister robots, has a simple task in life: to deliver packages along the last mile from a delivery van, that they all share as a home, to their final destination – and return. However, this seemingly simple task entails knowing all sorts of information about local regulations as well as being able to access live data from sensors to avoid collisions with her sister robots and other obstacles along the route, including humans, pets, wild animals, potholes, and other obstructions.

Her parent van is a level 4 AV with a broad ODD, and it has a human operator to address any problems that might occur. One morning the van drives to and parks at a location that it has determined is a valid parking spot for a delivery vehicle and is reasonably centrally located to all twelve final delivery points. The van then opens its doors, and all twelve robots swing into action to disperse and deliver packages.

Even though Rosie is only two blocks away from her delivery location, she is informed that she is not allowed to operate on the intervening sidewalk due to construction activities. Nor is she allowed to operate on the sidewalk on the other side of the road – the local regulator determined that the foot traffic in the area was high enough that the single sidewalk on the street should be limited to human users. And due to her small engine, Rosie is not allowed to operate in the travel lanes of the street. Instead, she is forced to find an alternate route using only sidewalks, which takes her to locations that have not been recently mapped by the delivery firm.

As Rosie traverses the planned path, dodging various pedestrians and e-scooters along the way, she encounters a section of sidewalk that is obstructed by a box. This obstacle is not a problem for most humans, they are just stepping off the curb and proceeding on their journey, but Rosie is not allowed (and not equipped) to do this. Instead, she notifies her parent van of the situation, and the van reroutes her to use yet another diversion route. The van then notifies its central office, which notifies the NMRAP to investigate. Rosie eventually makes her delivery and returns to her van to meet up with all of her other sisters.

In the meantime, the NMRAP verifies the blockage and issues a warning of a sidewalk limitation at the location. This information then becomes available to other users in the area that indicate their plans to use that sidewalk if they happen to have sidewalk requirements that exceed the current limitation (e.g., vulnerable road users in wheelchairs).