

Connected, Automated, Driverless, Electric, Shared, Mobility-as-a-Service Transportation.

Or, a glossary for the 3 Revolutions

The title of this glossary is intentionally jargon-laden. This reflects the similarly opaque language pervasive in discussions about the future of transportation. If we don't speak the same language, it will be challenging to set policy for the future of transportation. This guide will help parse what people mean by these terms. This glossary is a work in progress, feedback is appreciated.

The "3 Revolutions" for transportation refers to a future where travel is shared, automated, and electric. Each of these revolutions include a host of topics with its own complicated vocabulary that is often misused or misunderstood. This glossary is divided into sections covering each of these 3 revolutions. It also includes a section on connected vehicles, which is a set of supporting technologies that may support the other revolutions. Options from each of these categories can also be combined, and the 3 Revolutions will be most impactful if they all come together - shared, automated, and electric.

Automated:

Automated vehicle (AV). A vehicle including some driving automation technology that can vary for different levels of human driver intervention. Can be applied to any level of automation above 0. SAE recommends using this term for the driving of the vehicle rather than the vehicle itself. SAE suggests "driving automation system-equipped vehicle" (ADS-equipped vehicle) use when referring to level 3,4 or 5 and "driving automation capability" of a vehicle for levels 1 or 2. Not all automated vehicles are autonomous (a term synonymous with the term self-driving) or driverless (see below).

Highly automated vehicle (HAV). A vehicle including high levels of driving automation technology capable of some or all operation without direct human control. These vehicles may or may not have directly human operated controls (such as a steering wheel and pedals). HAV is synonymous with level 4 and 5 automation, and includes both self-driving (level 4) and driverless (level 5).

Autonomous. A vehicle that can (but does not necessarily always) operate without any input from a human driver or significant external control. Can be synonymous with level 4 and 5 automation. Autonomous vehicles are a subset of automated vehicles. Also referred to as self-driving.

Advanced Driver Assistance Systems (ADAS). Integrated vehicle systems that improve vehicle driving operations enhancing its performance and safety. ADAS, especially when combined, suggest a certain level of automation in a vehicle (levels 1 to 3), but not generally a highly automated vehicle (level 4 or

5). Some examples include adaptive cruise control (ACC), lane departure warnings, park assist, surround view, forward collision avoidance, automatic emergency braking (AEB), and adaptive lighting.

Driverless. A vehicle that operates without any input from a human driver. This term can be synonymous with level 5 automation. Driverless vehicles are a subset of automated and autonomous vehicles.

SAE Levels of Automation. Driving automation is a term used by the Society for Automotive Engineers (SAE) to refer to the use of electronic or mechanical devices to perform driving operation tasks of a vehicle. SAE J3016 defines the levels of automation from 0 to 5.

Level 0: No driving automation, all driving tasks are performed by the human driver.

Level 1: Requires the interaction of both, the human driver and the system to perform the driving tasks associated to steering and acceleration or deceleration. The rest of the tasks are implemented by the driver. Also referred to as assisted driving.

Level 2: The tasks shared in Level 1 are now performed completely by the system, and the driver implements monitoring activities of the driving environment such as object recognition and the corresponding response to that event. Also referred to as partial automation.

Level 3: Both operational and tactical activities mentioned in Level 3 are now performed by the system, requesting the human driver to intervene when there is different condition or environment for the automated system such that it's not able to operate, i.e. in the case of an accident or emergency context. Also referred to as conditional automation.

Level 4: A high level of automation where the system performs all the driving tasks incorporating additional functionality in the case of a fallback as in Level 3. In this sense, it is not expected the intervention of the driver at any point but the system can allow for a temporary action of the driver in the case of a system failure. Also referred to as high automation or self-driving.

Level 5: Full automation stage where all driving modes are performed by the system. Also referred to as driverless.

X as a Service (XaaS). A term adopted from the software community, which refers to any function provided to a user without the user needing to understand or manage the implementation of that service. Web applications are the most widely used implementation of software as a service, where the providing company manages all aspects of the installed software rather than requiring it to be installed on the user's computer.

Transportation as a service (TaaS) is the application of XaaS to transportation, including:

Vehicle- as-a-service (VaaS). Transportation services incorporating fully-automated driving vehicles (level 5) that is aimed to serve as a fleet for companies or groups of people. Also known as car-as-a-service. Rental cars can be considered an early VaaS because they provide a vehicle to the user and handle most management and maintenance of the vehicle behind the scenes.

Mobility-as-a-service (MaaS): integration of multimodal transportation services through one interface or application that provides end-to-end mobility options. The system simplifies the booking, payment and preferred transportation modes of these services. Also known as transportation-as-a-service or TaaS, though MaaS sometimes implies access to a wider set of mobility-like options such as virtual presence.

Each of these TaaS options could or could not be automated to various degrees.

Connected:

Connected as a category refers to vehicles that are able to communicate, either directly or through intermediaries, with other vehicles, infrastructure, and devices.

Vehicle to X or V2X. Connectivity between vehicles and services. The X refers to the any other entity with which the vehicle is communicating. Automated vehicles may or may not be connected, and connected vehicles may or may not be automated. The two technology sets may support each other, with connectivity making some automation applications (for example, platooning) easier to achieve.

Vehicle-to-vehicle (V2V). Communication established between vehicles to exchange information of the driving environment. This can include basic safety information such as the vehicle's speed and direction or more detailed information such as road and traffic conditions. Because of the importance of low latency in these applications, most proposed approaches are direct between vehicles (rather than mediated through the cloud).

Vehicle-to-infrastructure (V2I). This term refers to connectivity between the vehicle and infrastructure. This could include communication with traffic signals to time arrival at the intersection with green lights and smart lane markers that can be perceived even when visually obscured (for example by snow).

Vehicle-to-pedestrians/bicyclists (V2P/B). This term refers to connectivity communication between the vehicle and pedestrians or bicyclists. Possible applications include warning non-drivers of dangerous situations, or preparing vehicles for a pedestrian or bicyclist the vehicle cannot yet perceive directly.

Types of connectivity: Many vehicles that are automated, shared, or conventional will use communication protocols (4G, WiFi, DSRC, etc.) to support their operation, including communicating with the cloud for mapping and navigation, GPS, reporting traffic or road condition, and vehicle software updates.

Shared:

Shared in general means increasing the occupancy of vehicles by sharing use between parties that are not naturally travelling together as a party, which reduces impacts such as congestions and emissions.

Carsharing. A service in which members have access to vehicles that they do not own for short terms by paying a membership and associated prices. There are many configurations that allow pick-up and drop-off of vehicles in the same or different locations or that serve a specific group or population. Carsharing services are not necessarily pooled or shared travel since they are often still single occupancy or used by a group that was already traveling together.

Pooling. Any travel situation where riders share a vehicle for part or all of a trip where the riders would otherwise not be all travelling together. Carsharing and ride hailing are not necessarily pooled, ridesharing is.

Ridesharing. Allows for additional passengers to join an existing trip and maximize the use of a vehicle capacity. Drivers are not "for-hire" but may receive other compensation. Also referred to as carpooling, vanpooling and real-time or dynamic ridesharing.

Ride hailing. Platforms in which providers of transportation network companies (TNCs) connect passengers and drivers of otherwise non-commercial vehicles. Ridesharing services are not necessarily pooled or shared travel since they are often still single occupancy or used by a group that was already

traveling together. Also referred to as ride sourcing or on-demand ride services. Ride hailing services are not necessarily pooled or shared travel since they are often still single occupancy or used by a group that was already traveling together. Some TNCs offer pooled ride hailing, which can be true shared travel.

Electric:

In general, electric or electrified transportation refers to the set of vehicle technologies where electric power is at some time used to help move the vehicle. This includes a wide range of specific technologies and levels of electrification.

Hybrid-electric vehicles (HEV). Vehicles with two propulsion sources, usually a liquid fuel such as gasoline and an electric motor. There are multiple possible configurations ranging from mild to full (referring to the fraction of motive power that can be provided by electric motor). HEVs do not plug in to the electric grid, so all energy used by the vehicle comes from the liquid fuel. The electric portion of the drivetrain increases efficiency.

Plug-in electric vehicles (PEV). Vehicles that run partially or entirely using battery power that is recharged through the electric grid. PEVs include:

Electric vehicles or battery electric vehicles (EV / BEV) run on electricity stored in batteries and have an electric motor. They cannot run on liquid fuels.

Plug-in hybrid electric vehicles (PHEV) that have one electric motor relying on a battery and a gasoline or diesel engine. There are two main operation modes: 1) the vehicle runs only on electric mode until the engine provides energy to the batteries, 2) the vehicle run on both electric and gasoline modes after the all-electric range is over. Certain architectures of PHEV are sometimes referred to as extended range electric vehicles (EREV).

Fuel cell electric vehicle (FCEV) are also electric vehicles in that their motive power is provided by an electric motor and they contain a battery to store electric energy. The difference from PEVs is that FCEVs powered by hydrogen which is stored in a tank and then converted by the fuel cell to electricity. Some FCEV architectures also allow plugging in the vehicle. This is referred to as a fuel cell hybrid electric vehicle, which combines a fuel cell and battery system.

More Resources:

- https://www.sae.org/misc/pdfs/automated_driving.pdf
- <http://beta.fleetowner.com/blog/sorting-out-self-driving-terminology>
- <https://newsroom.intel.com/wp-content/uploads/sites/11/2017/05/Autonomous-Driving-Glossary.pdf>
- <https://roboticsandautomationnews.com/2017/07/01/adas-features-of-advanced-driver-assistance-systems/13194/>
- <https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety>
- https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/v2v_nprm_web_version.pdf
- <http://ieeexplore.ieee.org/document/7835924/>
- <https://medium.com/@BotmetricHQ/the-rise-of-anything-as-a-service-xaas-the-new-hulk-of-cloud-computing-5eca37c2ff02>
- http://sharedusemobilitycenter.org/wp-content/uploads/2015/09/SharedUseMobility_ReferenceGuide_09.25.2015.pdf
- https://www.driveclean.ca.gov/pev/Plug-in_Electric_Vehicles/BEVs.php