Where will Automated Vehicles take us? A Framework for Impact Assessment

Defining the Automated Vehicle System

Purpose
- Person travel (residents, visitors, persons with disabilities, etc.)
- Freight (type and size of shipments)

Service type
- Short haul / long haul
- Individual / group
- Fixed route, non-fixed route
- Specialized (e.g., valet parking)

Vehicle ownership / management / maintenance
- Privately owned single vehicle vs. fleet

Vehicle type
- Lightweight vehicle (e.g., golf cart)
- Automobile / pod
- Bus
- Truck

SAE level of automation

Available automated driving functions
- Vehicle control
- Monitoring of driving environment
- Dynamic routing
- Communications with other road users

Operational design domain (ODD)
- Exclusive AV vs. mixed environment
  - Non-automated motor vehicles
  - Pedestrians, bicycles
- Type of road (limited access, arterial, local)
- Types of intersections (merge, signal, stop/yield)
- Mapping infrastructure
- V2V, V2I, V2P communications infrastructure
- Road surface and markings
- Daytime / nighttime
- Weather (visibility, road surface condition, temperature, etc.)

Photo Source: USDOT | Photo Source: Thinkstock | Photo Source: USDOT | Photo Source: Thinkstock | Photo Source: TRL Ltd. GATEway project

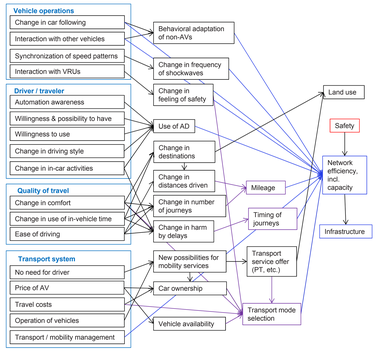
SAE Level of Automation

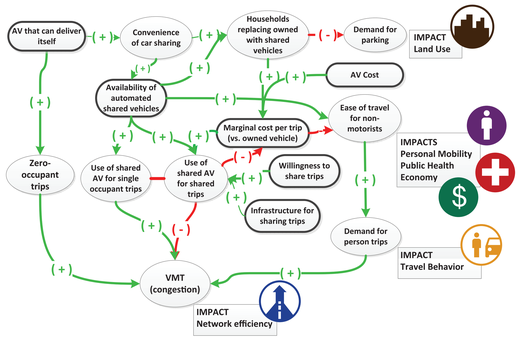
SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human driver	Some driving modes
4	High Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver	System	System	System	All driving modes

Source: SAE International

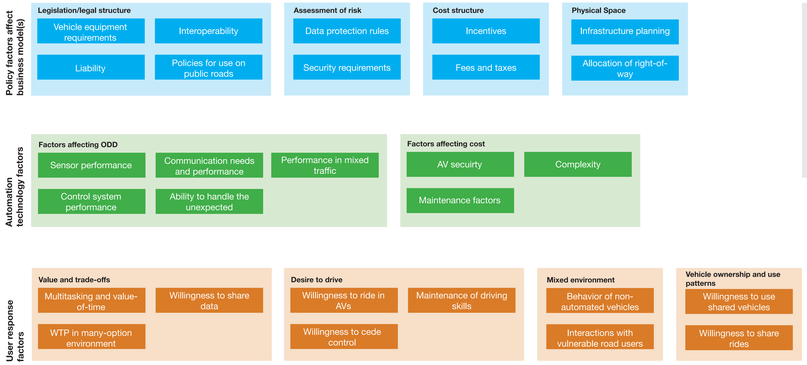
Impact Mechanisms

As there are different levels and concepts of automation, no single approach can be recommended for all impact assessments. Yet, our Framework indicates potential impact paths starting from direct impacts on vehicle operations, driver or traveler, quality of travel and transport system. These graphs are not inclusive but they can be used as a starting point for systematically determining the impact paths. Naturally, there are strong links between impact areas. Thus, assessment of indirect impacts is also recommended.





Uncertainties



Aspects of automation that will affect indirect impacts
- Extent of the operational design domain (ODD) for L4 vehicles
- Vehicle and data ownership
- Capital and marginal cost of transport
- Sharing of vehicles
- Sharing of journeys

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Direct Impacts

		Examples of Key Performance Indicators
Safety	Safety primarily considers harm from crashes to vehicle occupants and other road users. Other road users may include pedestrians, bicyclists, slow-moving vehicles, construction workers and first responders. Nearly all AV applications, ranging from Level 1 collision avoidance systems to Level 5 self-driving vehicles, have potential safety impacts. A challenge with safety assessment is that actual crashes are rare events; therefore, proxy measures are often used.	• Normalized number of fatalities, injuries and crashes • Conflicts with TTC less than a selected threshold • Instances of hard braking • Selected traffic violations • Instances where driver must take control • False positives (vehicle takes unnecessary action) • Unsafe actions by the vehicle (subjective)
Vehicle Operations	Vehicle operations include acceleration, deceleration, lane keeping, car following, lane changing, gap acceptance: all affect highway capacity. Relevant automation applications include those which provide longitudinal and/or lateral control with respect to the road and other vehicles.	• Speed variation and jerk • Lateral position variation and jerk • Mean and minimum time headway to lead vehicle • Gap acceptance
Energy / Emissions	Energy and emissions includes both the energy consumption of the vehicle through a driving cycle, and tailpipe emissions of pollutants including greenhouse gases. The direct energy/ emissions impacts come from the change in the driving cycle.	• Vehicle energy consumption • Vehicle CO2 emissions • Criteria (NOX, CO, PM10, PM2.5, VOC) emissions • Vehicle noise level
Personal Mobility	Mobility from a user's standpoint includes journey quality (comfort), travel time, cost; and whether the travel option is available to someone (e.g., a non-motorist). The higher levels of automation will have the most significant impacts, by providing mobility for non-motorists and enabling multi-tasking. Challenges in measuring personal mobility impacts include the variety of sub-populations who may be affected in different ways, and the difficulty in assessing the actual value of automation to a person. In the context of a fleet operation (trucking or transit), it is the direct impact on labor. Is the driver still needed? What happens to driver productivity (ability to multi-task or reduced fatigue)?	• Types of travelers who can use the vehicle • Journeys per day • Time and distance traveled per day • Travel time savings • Perceptions of quality, reliability and comfort • Ability to carry out other activities while in the vehicle

Indirect Impacts

		Examples of Key Performance Indicators
Network Efficiency	Network efficiency refers to lane, link and intersection capacity in a regional transport network. It also refers to travel time and travel time reliability. Improved safety may improve network efficiency via reduced incident delay. Also, changes in vehicle operations (e.g., car following) will affect network efficiency	• Road capacity (at design speed and maximum) • Throughput • Mean and 95th percentile travel time • Intersection capacity
Travel Behavior	A traveler may respond to AV options, including new service offerings, by changing travel behavior. There may be more trips. Modes and destinations may change. Higher level automation applications that have a significant effect on personal mobility or labor could have a significant effect on travel behavior.	• Number and type of trips per week • Duration and distance traveled • Mode split • Share of used road types • Network-level journey time
Public Health	Automation may impact the health of communities, via safety, air pollution, amount of walking and bicycling, as well as access to medical care, food, employment, education and recreation.	• Quality-adjusted life years • Population exposure to air pollution • Use of active modes (walking, bicycling) • Access to health services and recreation
Land Use	Automation may affect the use of land for transport functions (e.g., parking, road geometry). Longer term land use changes may include location and density of housing, employment and recreation.	• Density and location of land uses • Amount and location of parking • Allocation of highway right-of-way (Motor traffic, bicycle, pedestrian, green space)
Socio-Economic	Improved safety, use of time, freight movement, travel options for non-motorists, public health, land use and effects of changed emissions (including climate change) will have longer term economic impacts. Automation may also have substantial impact on labor markets and industries.	• Work time lost from crashes, air pollution • Work time gained by multi-tasking • Labor force participation • New jobs • Jobs eliminated • Socio-economic cost benefit ratio

Would you like to see better KPIs, that can be compared for projects around the world?
Please see connectedautomateddriving.eu/news item of 12 June 2017, titled "Participate in KPI Survey for Automated Driving," for a link.

Scott Smith
Volpe Center / US DOT
Scott.Smith@dot.gov

Satu Innamaa
VTT-Technical Research Centre of Finland
Satu.Innamaa@vtt.fi

Yvonne Barnard
University of Leeds
Y.Barnard@leeds.ac.uk

Helena Gellerman
SAFER - Chalmers University
helena.gellerman@chalmers.se

Ryota Horiguchi
I-TransportLab
rhoriguchi@i-transportlab.jp

Hannah Rakoff
Volpe Center / US DOT
Hannah.Rakoff@dot.gov