Technology of Autonomous Vehicles –
basic concepts, types, operational characteristics

developments:

- vehicle technology
- infocommunication
- energetics

smart and connected vehicle (V2X)

V2I: traffic sign, emergency situation, etc.

V2V: location sharing, emergency situation, etc.

alternative fuels - electromobility

Automated functions

- programmed rules
- predetermined, step-by-step, clearly described
- manage known situations

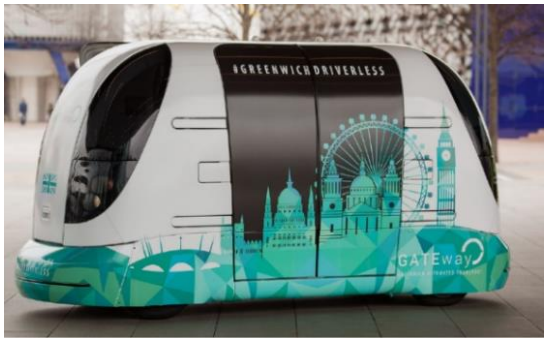
Autonomous functions

- data collection: perception/from other sources
- cognitive capabilities, individual decision making
- manage not known situations

cognitive capability:
recognition and persistent learning capability
create new, reliable, value-added information
use experience, knowledge, secondary information sources

Automated vehicles
separated track, closed from the traffic

Autonomous vehicles
unseparated track in the traffic



Automation levels – vehicle control

SAE | Society of Automotive (USA)
BASt | Bundesanstalt für Straßenwesen (Germany)
NHTSA | National Highway Traffic Safety Administration (USA)

	SAE levels	BASt levels	NHTSA levels	execution of steering and acceleration/ deceleration	monitoring of driving environment	fallback performace of dynamic driving task	system capability (driving modes)
0	no automation	driver only	0	human driver	human driver	human driver	-
1	driver assistance	assisted	1	human driver and system	human driver	human driver	some drivng modes
2	partial automation	partially automated	2	system	human driver	human driver	some drivng modes
3	conditional automation	highly automated	3	system	system	human driver	some driving modes
4	high automation	fully automated	3/4	system	system	system	some drivng modes
5	full automation	-		system	system	system	all driving modes

source: SAE International

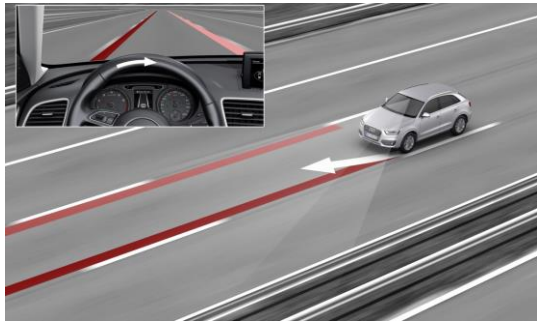
available new vehicles today: SAE 1-2

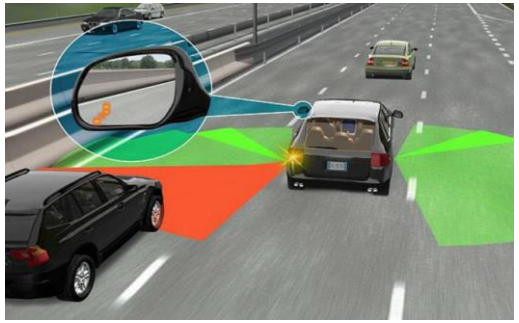
developments in test phases:

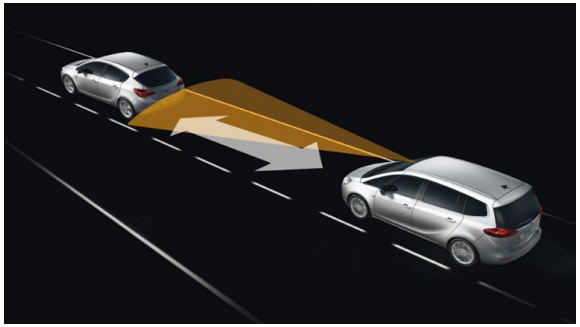
- Tesla autopilot system (SAE 2)
- driverless pods, Google/Waymo, UBER (SAE 4)

Available driver assistance functions

- warning
  e.g. lane keeping assistance, blind spot detection, distance warning system,
- emergency assistance
  e.g. ASR - Anti Slip Regulation, ESP - Electronic Stability Program, adaptive brake assistance,
- improving capacity and efficiency
  e.g. tempomat, traffic light assistance,
- improving comfort
  e.g. parking assistance







Devices for self-driving

Hardware devices:

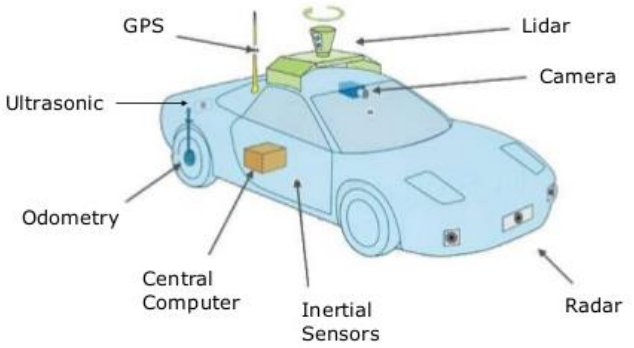
- GPS – localization (+network map!)
- LIDAR – distance measure -> point cloud (3D)
- camera – traffic sign, traffic light, lane recognition
- radar – distance keeping
- sensor – environment detection – e.g. LGPR

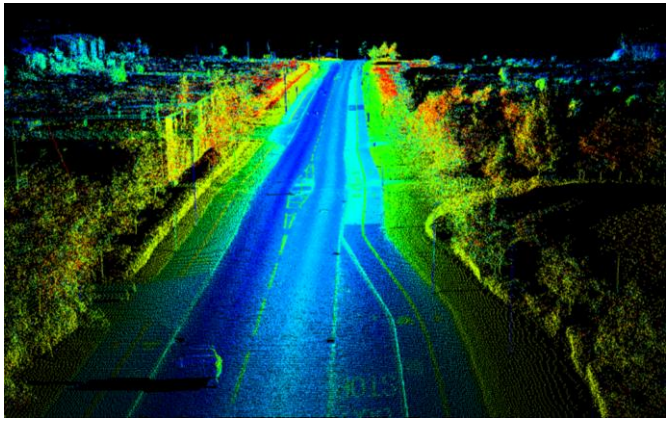
Software devices – decision making:

automated image recognition, artificial intelligence - persistent learning

LIDAR can be replaced: cameras (360° angel of view, monocamera + AI)

Autonomous vehicle is a rolling IT device



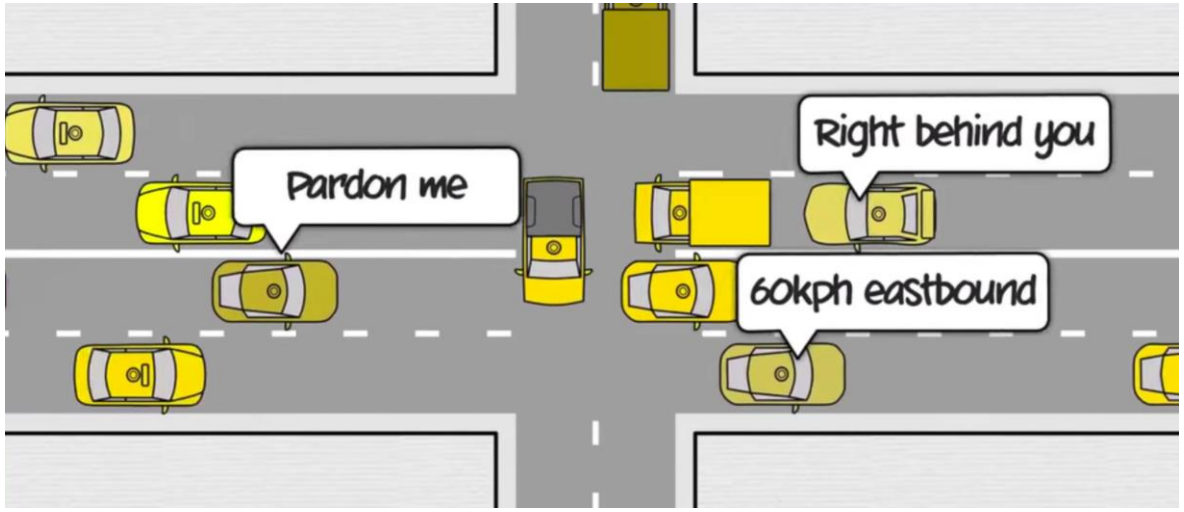


Intelligent road infrastructure

where is the intelligence? – vehicle vs. infrastructure

- sensors (e.g. weather, road condition, traffic situation)
- V2I: messages between vehicle and infrastructure
- V2V: messages between vehicles – without road signs/markers

BUT! road signs/markers are necessary for soft mobility modes



International practice

sub-system development vs. entirely vehicle development

vehicle conversion vs. new vehicle

test environment: closed test track vs. existing (urban/motorway area)

developers:

conventional vehicle manufacture/
supplying industry/IT company/start-up

Who do you trust better?

development goal:

service oriented (UBER)/product oriented (Tesla)

What will be the transportation in the future?

TEST PHASE – accompanying staff
(wheels/pedals and emergency stop button)

goal: experience collection – machine learning

passenger reaction analyzing

types of development:

- car: Tesla, BMW, Audi, UBER, Google/Waymo's
- small bus – pod: Easymile, Navya Arma, Local Motors
- *bus*: Mercedes
- *truck*: Volvo (Otto)

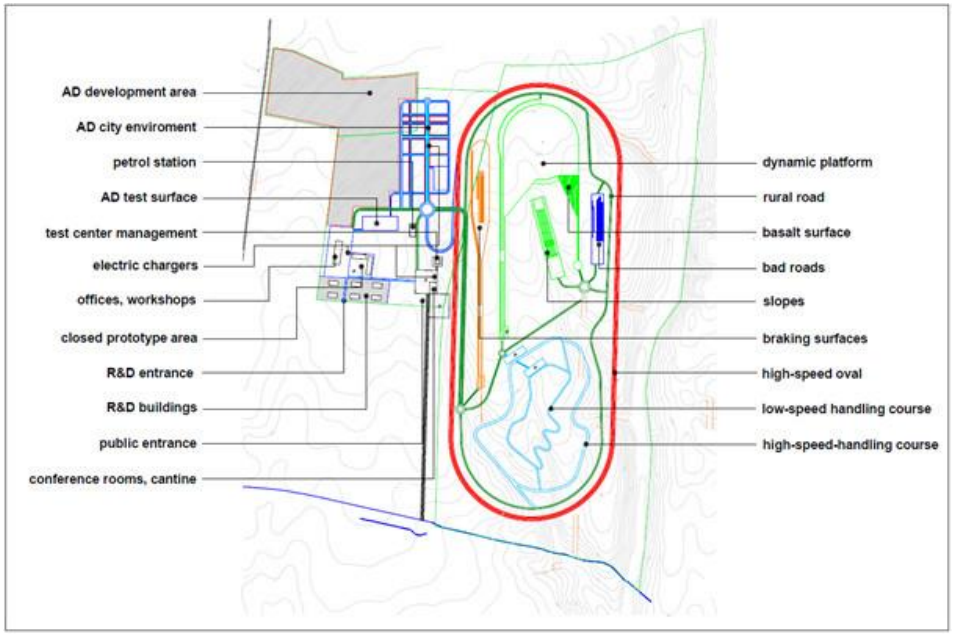
pod-like services in **test**:

- Berlin: university campus (DB)
- Berlin: hospital buildings (BVG)
- Vienna: smart city quarter (WienerLinien)
- Wageningen–Ede, Netherland:
  between cities in public roads
- Civaux, France: nuclear power station
- Citymobile2 EU project (Trikala, Vantaa, La Rochelle)

- isolated areas
- fix timetable or route

Hungary:

- university researches
- RECAR – research center
- education - Autonomous Vehicle Control Engineer - MSc (BME-ELTE) – expected launch: 2018 autumn
- ZalaZone Zalaegerszeg - Autóipari Próbapálya Zala Kft. – closed test track
- Budapest, Szépvölgyi út - test environment in public roads - AImotive Kft.

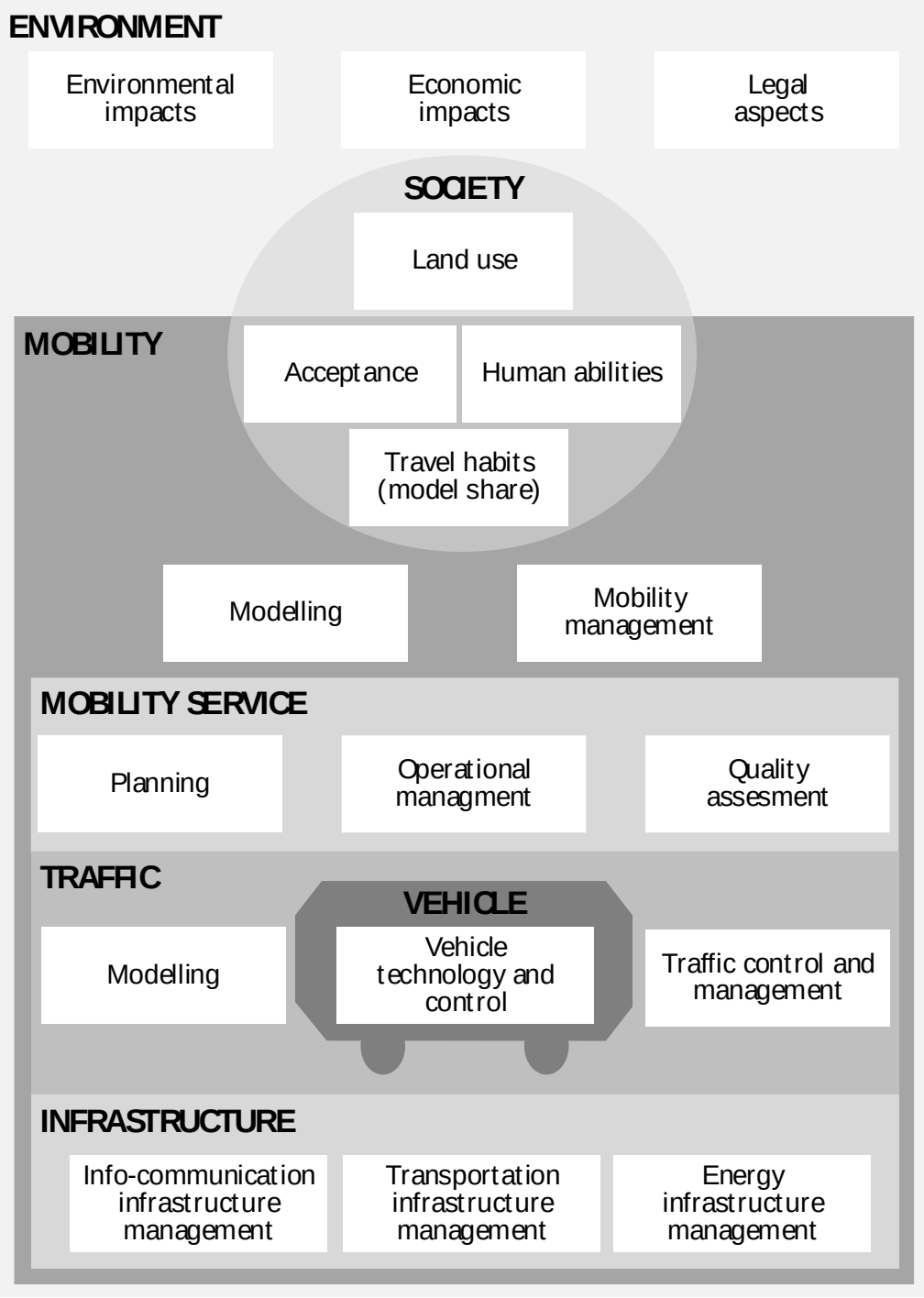


Model of Transportation System and Mobility Services based on Autonomous Vehicles

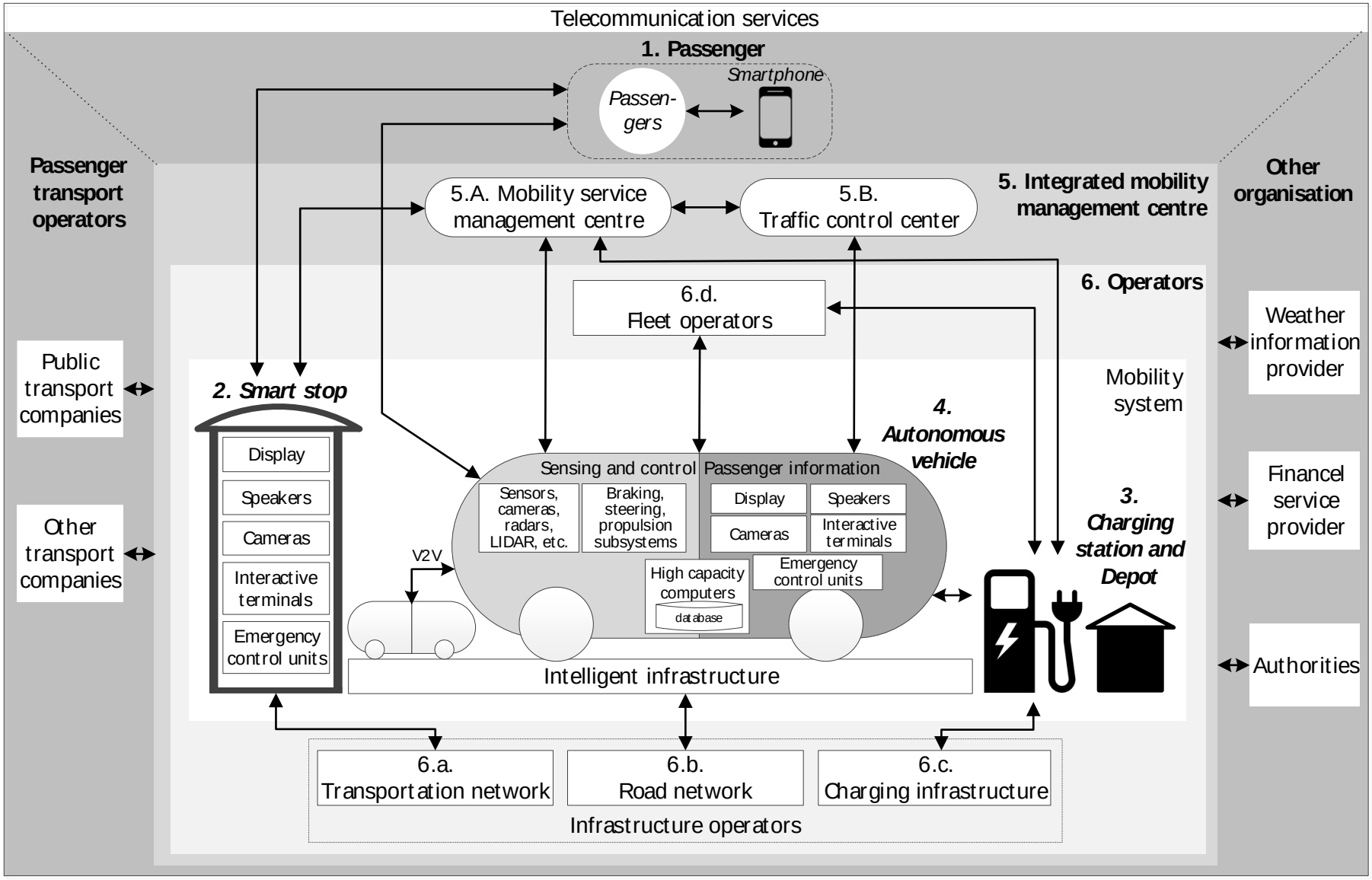
Model of transportation system

complex system

generate alterations



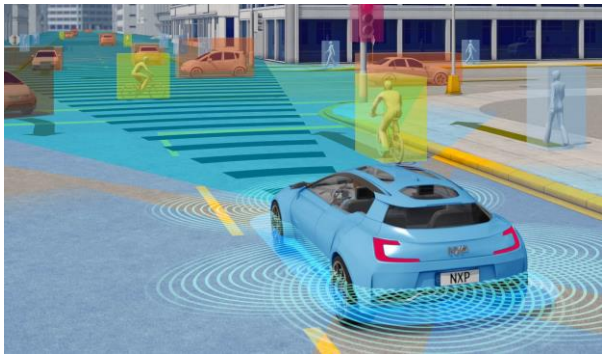
System architecture



the (passenger) transportation transfer into a special information system

System components

1. Passenger – with smart device
2. Smart stop
3. Charging station and Depot
4. Autonomous vehicle
5. Integrated mobility management centre
   A. Mobility service management centre
   B. Traffic control centre
6. Operators
   a. Transportation network
   b. Road network
   c. Charging infrastructure
   d. Fleet



autonomy is a relative concept

Integrated mobility management centre

Mobility management centre

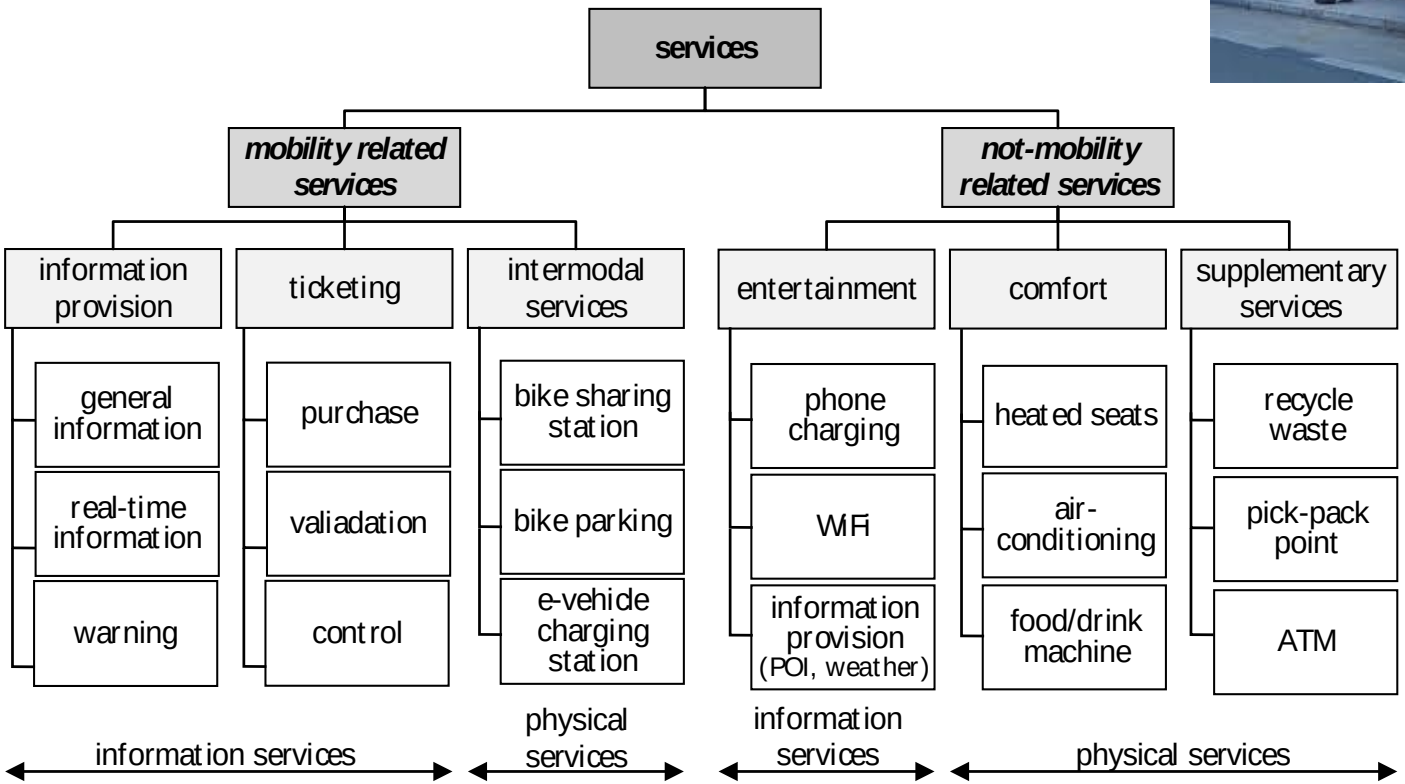
- planning
- organizing
- control of mobility process

Traffic control centre

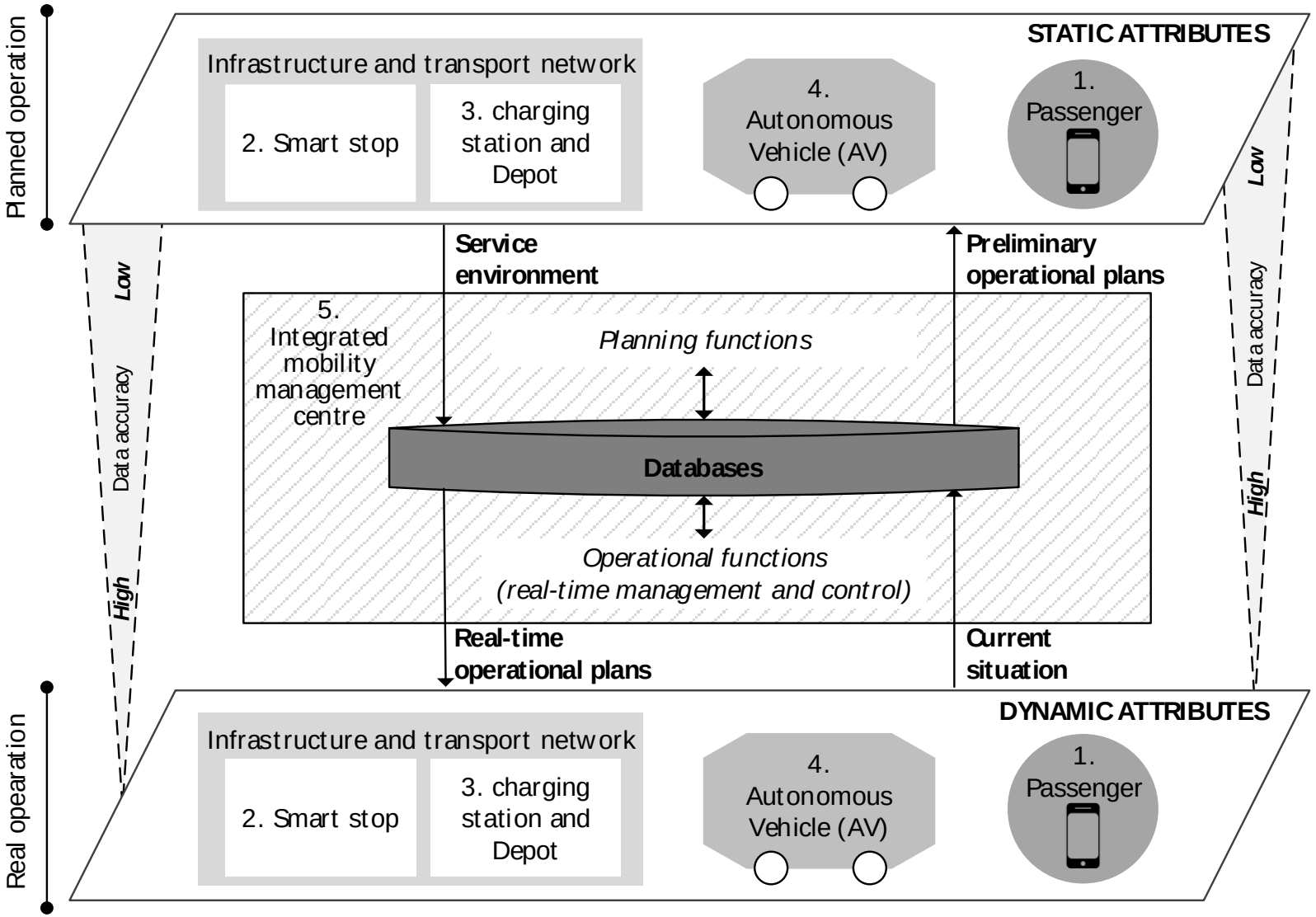
- control and prediction of traffic parameters
- provision of real-time traffic information
- data exchange with road network operators
- statistical analysis of traffic parameters supplying data for the decision-making

Smart stop

- equipped with devices → improve physical and mental comfort
- automated/autonomous functions
- mobility related and not-mobility related services
- renewable energy sources
- high comfort level
- intermodal facilities



Operational model



system dynamism – management of real-time data

Current automated (autonomous) transportaiton modes

(aviation – robotpilot)

underground

people mover

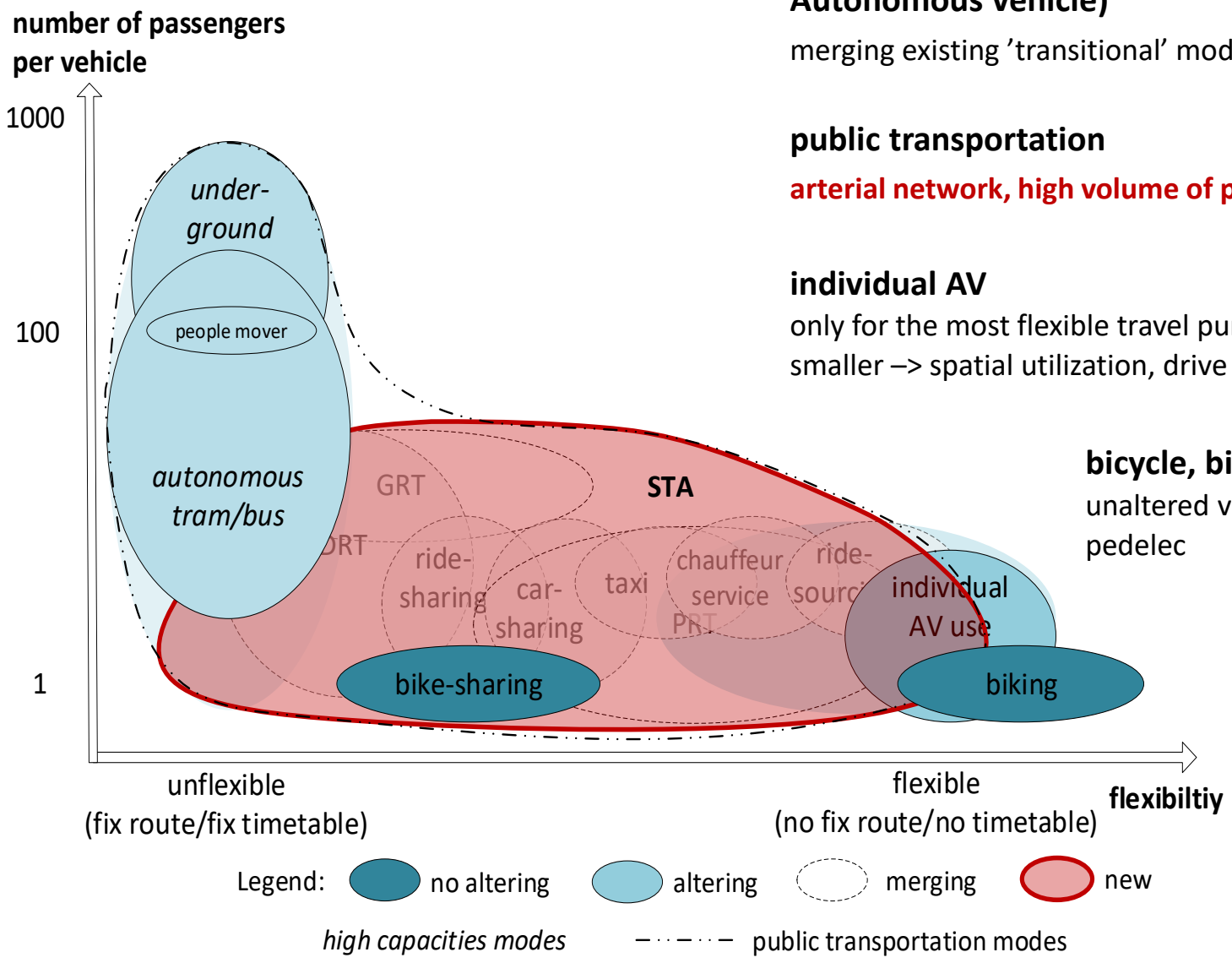
GRT (Group Rapid Transit)

PRT (Personal Rapid Transit)

ride-sourcing (ride-hailing) - taxi

- UBER, Grab, Google/Waymo
- test phase

Alteration in transportation modes



STA (Shared Transportaiton based on Autonomous vehicle)

merging existing 'transitional' modes

public transportation

arterial network, high volume of passenger

individual AV

only for the most flexible travel purposes

smaller –> spatial utilization, drive into buildings

bicycle, bike-sharing

unaltered volume

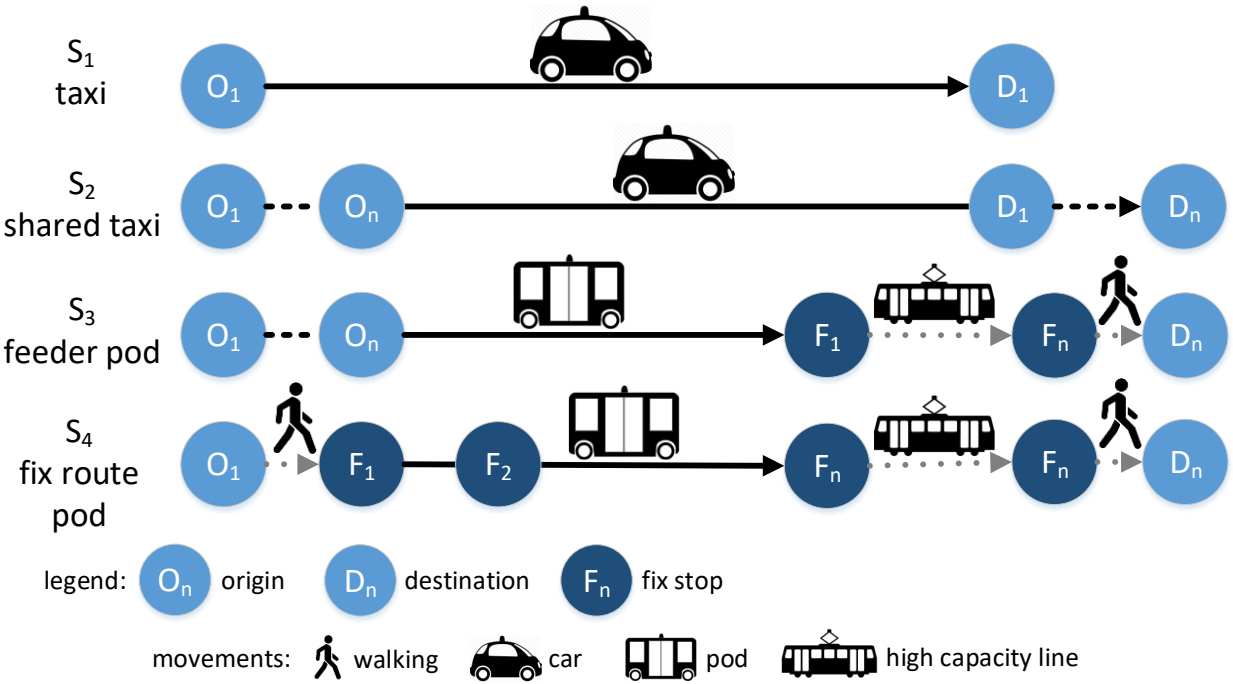
pedelec

service-oriented approach instead of vehicle-oriented approach

STA service types

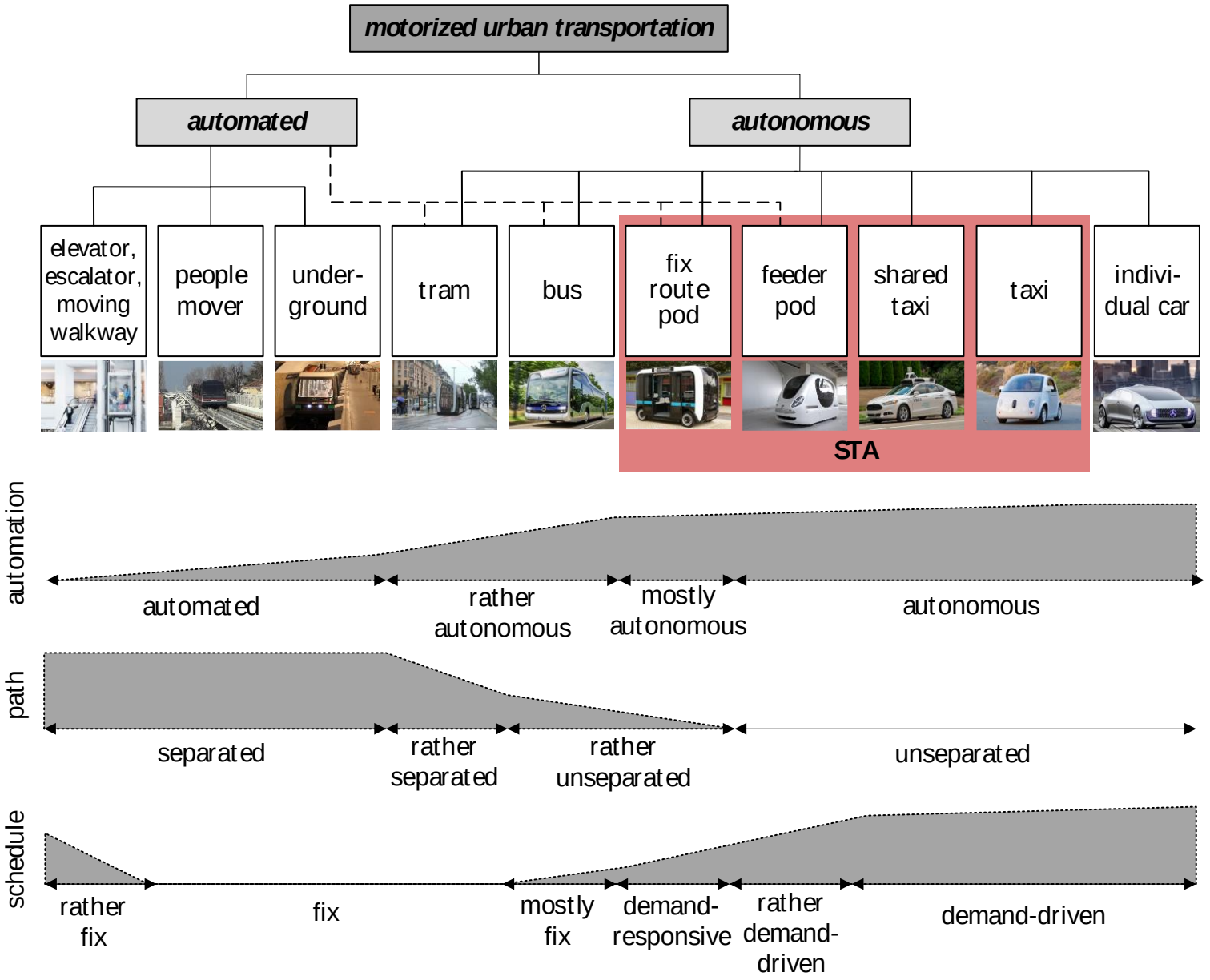
- small-capacity
- demand driven (demand-responsive)
- door-to-door/feeder
- advance ordering
- customized
- mobil application based

transportation is more personalized but planned in advance



	S_1 taxi	S_2 shared taxi	S_3 feeder pod	S_4 fix route pod
Vehicle type	Car	Car	Pod	Pod
Sharing	No	Yes	Yes	Yes
Modality	Door-to-door	Door-to-door	Feeder	Feeder
Capacity	Demand-driven	Demand-driven	Rather demand-driven	Demand-responsive
Scheduling	Flexible	Flexible	Semi-fix (guaranteed transfer)	Fix (additional departures)
Boarding point	Flexible	Flexible	Semi-fix (only in the zone)	Fix stop
Alighting point	Flexible	Flexible	Fix stop	Fix stop
Route	Flexible	Flexible	Semi-fix (fix arrival stop)	Fix
Access walking	No	No	No	Yes
Egress walking	No	No	Yes	Yes

Categorization of motorized urban transportation means



Future categories of passenger transportation:

- Individual transportation
  - non-motorized: walking, biking
  - motorized: individual AV use (motorcycle use),
- Public transportation
  - small capacity
    - non-motorized: bike-sharing,
    - motorized: STA,
  - high capacity (mass transit) based on AVs (e.g. bus, tram) or highly automated vehicle (e.g. underground).

Future public transportation:

Accessible by anyone who is willing to pay a fare; the vehicle is operated by any type of companies (or private person); however, the services are regulated, managed (and controlled) by the mobility management centre.

Mobility-as-a-Service (MaaS) with autonomous vehicles

- vehicles managed by mobility management centres
- concept of MaaS – more efficient

	Conventional MaaS	MaaS based on AVs
Drivers	Necessary in most transportation modes	Elimination
Involved services	Public/semi-public/ private services	Public service
Passenger handling	Human-based and based-on application	Automated, based-on only application
Task coordination	Complicated (several operators)	More reliable, efficient coordination
Dispatching	Drivers need to respond	Automatic

Comparison of conventional and AV-based MaaS

Delivery

last mile collection/distribution (and long distance delivery)

- safety/security?
- parcel handling? – (un)loading, receipt (identification, payment)
- on ground/in the air (e.g. drone)

delivery-sourcing: e.g. UBEReats, Pickitapp

Combined ride-sourcing

order vehicle for traveling or sending package/purchase a product and home delivery