MOBILITY BASED ON AUTONOMOUS VEHICLES
OPERATION, INFORMATION MANAGEMENT

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1. Vehicle characteristics

What is the difference between automated system and autonomous system?
1. Vehicle characteristics

Automated functions
- programmed rules
- clearly described, step by step

Autonomous functions
- data collection: perception/from other sources
- cognitive capabilities, individual decision making

**autonomy is a relative concept**

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

developments:
• vehicle technology
• infocommunication
• energetics

smart and connected vehicle (V2X)

V2I: traffic sign, emergency situation, etc.
V2V: location sharing, emergency situation, etc.
1. Vehicle characteristics

driver assistance functions:
- ABS, ESP
- distance warning system
- adaptive brake assistance
- blind spot detection
- lane keeping assistance
- parking assistance – automated parking
- crosswind stabilization
- traffic light assistance
- etc.

collision prevention
1. Vehicle characteristics

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)*

AV is a rolling IT device
1. Vehicle characteristics

Automated vehicles
separated track, closed from the traffic

Autonomous vehicles
unseparated track in the traffic

alternative fuels - electromobility
# 1. Vehicle characteristics

<table>
<thead>
<tr>
<th>SAE levels</th>
<th>BAS levels</th>
<th>NHTSA levels</th>
<th>execution of steering and acceleration/deceleration</th>
<th>monitoring of driving environment</th>
<th>fallback performance of dynamic driving task</th>
<th>system capability (driving modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no automation</td>
<td>driver only</td>
<td>0</td>
<td>human driver</td>
<td>human driver</td>
<td>human driver</td>
</tr>
<tr>
<td>1</td>
<td>driver assistance</td>
<td>assisted</td>
<td>1</td>
<td>human driver and system</td>
<td>human driver</td>
<td>human driver</td>
</tr>
<tr>
<td>2</td>
<td>partial automation</td>
<td>partially automated</td>
<td>2</td>
<td>system</td>
<td>human driver</td>
<td>human driver</td>
</tr>
<tr>
<td>3</td>
<td>conditional automation</td>
<td>highly automated</td>
<td>3</td>
<td>system</td>
<td>system</td>
<td>human driver</td>
</tr>
<tr>
<td>4</td>
<td>high automation</td>
<td>fully automated</td>
<td>3/4</td>
<td>system</td>
<td>system</td>
<td>system</td>
</tr>
<tr>
<td>5</td>
<td>full automation</td>
<td>-</td>
<td>3</td>
<td>system</td>
<td>system</td>
<td>system</td>
</tr>
</tbody>
</table>

available new vehicles today: SAE2
developments in test phases:

• Tesla autopilot system (SAE3)
• driverless pods (SAE4)
2. 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/IT company

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
2. International practice

types of development:

• car: Tesla, BMW, Audi, UBER, Google (Waymo)
• 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)
pod – OLLI (1:25)
Bus – Mercedes-Benz (1:25)
2. International practice

Hungary:

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

Alteration in transportation modes

<table>
<thead>
<tr>
<th>Service types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS-DRT (Telematic-based Shared Demand Responsive Transportation)</td>
<td>merging existing ‘transitional’ modes</td>
</tr>
<tr>
<td>Public transportation</td>
<td>arterial network, high volume of passenger</td>
</tr>
<tr>
<td>Individual AV</td>
<td>only for the most flexible travel purposes</td>
</tr>
<tr>
<td>Bicycle, bike-sharing</td>
<td>unaltered volume</td>
</tr>
<tr>
<td>Pedelec</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- no altering
- altering
- merging
- TS-DRT

Service-oriented approach instead of vehicle-oriented approach
3. Service types

„Transitional modes” – shared, mobile application based, dynamic tariff system

ride-sharing (carpooling):
BlaBlaCar, Oszkár (inter-city traveling) / WAZEcarpool, BlaBlaLines (daily commuting)

car-sharing
Greengo

ride-sourcing (ride-hailing):
UBER, Lyft, Grab
• shared ride-sourcing (pl.: UBERpool)
• delivery-sourcing (UBEReat, Pickitapp)
• automatization willingness is relevant
  UBER, Grab (NuTonomy)
3. Service types

Automated public transportation:

- **Automated**
  - Elevator, escalator, travelator
  - People mover
  - Underground
  - Tram
  - Bus

- **Autonomous**
  - GRT (Group Rapid Transit)
  - PRT (Personal Rapid Transit)

**Legend:**
- Typical classification
- In case of specific situation
### 3. Service types

**TS-DRT characteristics:**

- small capacity (max 15 passengers) pod
- service types:
  - feeder service
  - door-to-door – more expensive
- reservation in advance
- flexible route, without timetable
- dynamic tariff system
- mobile application based
- high comfort – infotainment
- platooning

**Transportation is more personalized but planned in advance**

<table>
<thead>
<tr>
<th>Size of Vehicle</th>
<th>Sharing</th>
<th>Reservation Obligatory</th>
<th>Origin and Destination</th>
<th>Route</th>
<th>Timetable</th>
</tr>
</thead>
<tbody>
<tr>
<td>small sized (PRT)</td>
<td>no</td>
<td>yes</td>
<td>optional location</td>
<td>flexible</td>
<td>no</td>
</tr>
<tr>
<td>medium sized (GRT)</td>
<td>yes</td>
<td>no</td>
<td>fix (smart) stop</td>
<td>fix</td>
<td>fix</td>
</tr>
</tbody>
</table>

Legend: typical feature of PRT

Non-typical feature of PRT

Features of the modelled TS-DRT
3. Service types

Delivery

last mile collection/distribution (and long distance delivery)

- safety/security?
- parcel handling? – (un)loading, receipt (identification, payment)

delivery-sourcing: e.g. UBEReats, Pickitapp

Combined ride-sourcing

order vehicle for traveling or sending package/purchase a product and home delivery
4. Operation management

integrated mobility management centre

Integrated smart mobility management centre - Functions

Traveller information services

- F1 Personalized activity chain (route) planning
- F3 Road/parking reservation
- F5 Payment
- F7 Information about supplementary services

Operational functions

- F2 Seat reservation
- F4 Charging point reservation
- F6 Navigation/guiding/location based information
- F8 Safety/security functions
- F9 Route and schedule planning (PT, TS-DRT)
- F10 Operative control (PT, TS-DRT, bike-sharing)
- F11 Control of road traffic (signals, AVs)
- F12 Evaluation of services (feedback)

Legend:

- Basic processes
- Information flow
- Cooperation between functions
4. Operation management

Structural model of TS-DRT
4. Operation management

the (passenger) transportation transfer into a special information system
4. Operation management

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

<table>
<thead>
<tr>
<th>Services</th>
<th>Mobility Related Services</th>
<th>Not-Mobility Related Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Services</td>
<td>Information provision (e.g. real-time, warning)</td>
<td>Ticketing (e.g. purchase)</td>
</tr>
<tr>
<td>Physical Services</td>
<td>Intermodal services (e.g. bike-sharing)</td>
<td>Entertainment (e.g. phone charging, information about weather, POI, news)</td>
</tr>
<tr>
<td></td>
<td>Comfort (e.g. air-conditioning)</td>
<td>Supplementary services (e.g. recycle waste)</td>
</tr>
</tbody>
</table>
4. Operation management

environmental friendly, green energy

charging

• conventional: charging point (wired) – in the depo, in the street

  who charges the vehicle?

• automated charging
  – instant charging (pantograph)
  – inductive, wireless charging

smart technology (reservation, identification, payment)
personalized (mobile application based)

parking (in the depo) + charging
4. Operation management

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
4. Operation management

Operational and planning functions of TS-DRT

Planning functions

Operational functions

Basic processes

planning, organizational, operational and economic methods are altering
4. Operation management

Data structure of TS-DRT

Legend: → 1:N connection

- Infrastructure related tables (A-D)
- Vehicle related tables (E-F)
- Passenger related tables (G-H)
- Service related tables (I-O)

POINT (B) - smart stops, other boarding/ alighting points
ROUTE SECTION – DYNAMIC (D)
CLIENT (G)
RUN (I) and TRAVEL (K) – disaggregated into sections
OD (O) and FREQUENT DESTINATIONS (H) – planning purposes
5. Passenger handling

identified functions (1):

<table>
<thead>
<tr>
<th>function groups</th>
<th>functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>nr. name</td>
<td></td>
</tr>
<tr>
<td>1 infotainment</td>
<td>F₁₁ information provision about general conditions and supplementary services</td>
</tr>
<tr>
<td></td>
<td>F₁₂ information provision about current situation</td>
</tr>
<tr>
<td></td>
<td>F₁₃ personalized journey planning and guiding/navigation</td>
</tr>
<tr>
<td></td>
<td>F₁₄ activity chain planning</td>
</tr>
<tr>
<td></td>
<td>F₁₅ information provision by installed devices (in the stop/station)</td>
</tr>
<tr>
<td></td>
<td>F₁₆ on board information provision by on board devices</td>
</tr>
<tr>
<td></td>
<td>F₁₇ on board complaining/information request</td>
</tr>
<tr>
<td></td>
<td>F₁₈ communication between vehicle-passenger</td>
</tr>
<tr>
<td></td>
<td>F₁₉ entertainment</td>
</tr>
<tr>
<td>2 management of entitlement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F₂₁ seat reservation</td>
</tr>
<tr>
<td></td>
<td>F₂₂ payment</td>
</tr>
<tr>
<td></td>
<td>F₂₃ ticketing</td>
</tr>
<tr>
<td></td>
<td>F₂₄ check-in (ticket validation)</td>
</tr>
<tr>
<td></td>
<td>F₂₅ control of entitlement (ticket inspection)</td>
</tr>
</tbody>
</table>
5. Passenger handling

identified functions (2):

<table>
<thead>
<tr>
<th>function groups</th>
<th>functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>nr.</td>
<td>name</td>
</tr>
<tr>
<td>3</td>
<td>safety</td>
</tr>
<tr>
<td>4</td>
<td>security</td>
</tr>
<tr>
<td>5</td>
<td>management of passenger room/cabin conditions</td>
</tr>
<tr>
<td>6</td>
<td>management of feedbacks</td>
</tr>
<tr>
<td></td>
<td>functions</td>
</tr>
<tr>
<td></td>
<td>name</td>
</tr>
<tr>
<td>3</td>
<td>F₃₁ avoiding accidents between vehicle and passengers</td>
</tr>
<tr>
<td></td>
<td>F₃₂ handling boarding process (warning, open/close door)</td>
</tr>
<tr>
<td></td>
<td>F₃₃ handling passengers in diseased conditions</td>
</tr>
<tr>
<td></td>
<td>F₃₄ handling fire cases</td>
</tr>
<tr>
<td></td>
<td>F₃₅ handling traffic collisions - evacuation</td>
</tr>
<tr>
<td></td>
<td>F₃₆ handling vehicle technical failures (broke down)</td>
</tr>
<tr>
<td></td>
<td>F₃₇ handling equipment technical failures</td>
</tr>
<tr>
<td>4</td>
<td>F₄₁ property protection (individual/common)</td>
</tr>
<tr>
<td></td>
<td>F₄₂ life protection</td>
</tr>
<tr>
<td></td>
<td>F₄₃ emergency call</td>
</tr>
<tr>
<td></td>
<td>F₄₄ safeguard against terrorism</td>
</tr>
<tr>
<td>5</td>
<td>F₅₁ management of comfort (e.g. heating, lighting, cleaning)</td>
</tr>
<tr>
<td>6</td>
<td>F₆₁ complaining</td>
</tr>
<tr>
<td></td>
<td>F₆₂ crowd sourcing</td>
</tr>
<tr>
<td></td>
<td>F₆₃ lost and found</td>
</tr>
<tr>
<td></td>
<td>F₆₄ data collection from/about passenger</td>
</tr>
<tr>
<td></td>
<td>F₆₅ data collection from/about vehicle/infrastructure</td>
</tr>
</tbody>
</table>

automatization of safety critical functions is more relevant
5. Passenger handling

more automatized passenger handling functions

• vehicle – passenger communication
  via (individual) electronic device, automated perception

• reservation – travel planning
  connected functions: automated reservation after travel planning

• check-in (ticket validation)
  simple: via touchless mobile device
  automated: based on location and personal data

• payment
  automated: based on length and attributes of the travel

• handling emergency situations (fire, evacuation)
  automated machine recognition, action plans, rapid human teams
Automatization levels in public transportation

Planning + passenger handling + controlling functions

<table>
<thead>
<tr>
<th>no.</th>
<th>name</th>
<th>description</th>
<th>location of decision and execution</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no automation</td>
<td>The human role (passenger, driver, other personnel) is unavoidable, they execute all processes; there is no direct machine support.</td>
<td>human</td>
</tr>
<tr>
<td>1</td>
<td>machine assistance</td>
<td>The human is supported by machine. However, the role of human is rather significant.</td>
<td>human aided by machine</td>
</tr>
<tr>
<td>2</td>
<td>partial automation</td>
<td>A significant part of the processes is executed by machine. The human indicates and monitors the processes.</td>
<td>rather machine with human confirmation</td>
</tr>
<tr>
<td>3</td>
<td>full automation</td>
<td>Processes are completely operated by machine in an automatic way, the personnel attends as supervisor.</td>
<td>machine</td>
</tr>
</tbody>
</table>
6. Human behaviour

- new user groups
- share of traveller types is altering

**total individual utility of travelling is increasing**

- useful activities during travel
- infotainment
6. Human behaviour

required human abilities are altering, cognitive capability reduce
### 6. Human behaviour

#### Information management of travellers - properties

<table>
<thead>
<tr>
<th>Traveller</th>
<th>Walking</th>
<th>Bikeway</th>
<th>Bike-sharing</th>
<th>Public Transportation (PT)</th>
<th>DRT PT</th>
<th>Car-sharing</th>
<th>Taxi</th>
<th>Ride-sourcing</th>
<th>Car-pooling</th>
<th>Chauffeur service</th>
<th>Individual calculating</th>
<th>TS-DRT</th>
<th>Individual AV</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Volume of machine-based information</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
<td><img src="image13" alt="Graph" /></td>
</tr>
<tr>
<td>II. Volume of information content of other traveller’s behaviour</td>
<td><img src="image14" alt="Graph" /></td>
<td><img src="image15" alt="Graph" /></td>
<td><img src="image16" alt="Graph" /></td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
<td><img src="image19" alt="Graph" /></td>
<td><img src="image20" alt="Graph" /></td>
<td><img src="image21" alt="Graph" /></td>
<td><img src="image22" alt="Graph" /></td>
<td><img src="image23" alt="Graph" /></td>
<td><img src="image24" alt="Graph" /></td>
<td><img src="image25" alt="Graph" /></td>
<td></td>
</tr>
<tr>
<td>III. Required cognitive capability</td>
<td><img src="image26" alt="Graph" /></td>
<td><img src="image27" alt="Graph" /></td>
<td><img src="image28" alt="Graph" /></td>
<td><img src="image29" alt="Graph" /></td>
<td><img src="image30" alt="Graph" /></td>
<td><img src="image31" alt="Graph" /></td>
<td><img src="image32" alt="Graph" /></td>
<td><img src="image33" alt="Graph" /></td>
<td><img src="image34" alt="Graph" /></td>
<td><img src="image35" alt="Graph" /></td>
<td><img src="image36" alt="Graph" /></td>
<td><img src="image37" alt="Graph" /></td>
<td></td>
</tr>
</tbody>
</table>

Legend: the traveller is driver

Information management is different according to modes
7. Impacts

- increasing demands (new user groups, number of passengers, number of travels)
- new mobility forms:
  - number of vehicles and size of vehicles decrease
  - empty vehicle runs increase
  - daily performance increase
  - capacity utilization of seats increase
- headway decreases (platooning), speed increases
- capacity utilization increases, existing road infrastructure is appropriate
- needed parking capacity decreases (combined loading, parking, charging lots)
- less accident → less injury

Legend:
- reduce;
- highly reduce;
- increase;
- highly increase;

favourable alteration ;
unfavourable alteration.
Traffic flows get better (4:30)
7. Impacts

SAFETY
- improving traffic safety, less accident
- several development areas remain

drivers, as labor, are replaced
→ social tension
  altering personnel groups

law should be altering

ETHICAL DILEMMAS
  who is responsible? who makes decisions?
7. Impacts

street/urban landscape, life quality:
strict boundaries between infrastructure elements diminish
• less space is necessary for road traffic
• charging points?
• road signs/markers disappear/alter
emissions decrease (alternative fuel, better capacity utilization)

transitional periods (mix traffic)
• in automatization levels
• in traffic flows – proportion of AVs, proportion of different type of AVs - scenarios

altering urban environment, livable cities
THE FUTURE IS COMING IN A GREEN WAY
BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
Faculty of Transportation Engineering and Vehicle Engineering
Department of Transport Technology and Economics

THANK YOU FOR YOUR KIND ATTENTION!