Planning and Operation of Mobility Services based on Autonomous Vehicles

Planning

novelties/challenges

- neglecting drivers’ work regulation
- management of high volume of data
- no historical data about operation
- unknown user acceptance

Legend:
- preliminary service planning
- operative planning

Planning functions

Information service planning
- Mobile application services
- On-board services
- Travel assistance

Operative planning
- Run
- Maintenance

Basic service planning
- Service type
- Fix stop/route
- Capacity
- Charging infrastructure
- Fee collection
Preliminary service planning

Service type
• determining service types
• based on travel demand and expectations

Fix stop/route
• determining stop and waiting points locations, route and service area
• based on travel demand – forecasting, willingness to walk
• spatial coverage higher in comparison to conventional public transport

Capacity
• planning timetable, vehicle number
• based on travel demand in peak hours – forecasting, willingness to wait

Charging infrastructure
• determining charging location
• goal: minimalize empty runs - parking (in the depot) + charging
• types: conventional: charging point (wired) – in the depo, in the street
  who charges the vehicle?
  automated charging - instant charging (pantograph)
  inductive, wireless charging

Fee collection
• planning tariff structure and payment method; rate calculation method and variables
• dynamic rates – influencing demand
• based on current demand, capacities, sharing, ordering in advance
Mobile application services
• important! – passengers handling functions are aided (e.g. ordering, payment)
• planning service and quality regarding functions
• automatic real-time, personalized information

On-board services
• planning infotainment services (information + entertainment)
• personalized, location-based information

Travel assistance
• planning functions regarding the use of the service
• automated functions – replacing personnel attendance

Operative planning:
Run
• planning runs with and without passengers; operative timetable
• real-time demand-capacity coordination, planning of shared runs

Maintenance
• determining maintenance plans
• based on technical requirements, run mileage – forecasting, assumptions in the early phase
Model for the information system of planning

- service is planned by mobility management centre (or operator)
- close cooperation
- data collection, planning process aided by computer, highly automatized
- input data
  - external data sources (municipalities, operators)
  - survey – user expectations
  - operation
  - result of the planning (output)

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>Basic data of potential users (personal and mobility attributes) in a given territory</td>
</tr>
<tr>
<td>Territory</td>
<td>Territory attributes (e.g. Road network, fix stops)</td>
</tr>
<tr>
<td>Technical</td>
<td>Technical data about vehicles and charging facilities</td>
</tr>
<tr>
<td>Survey</td>
<td>Processed data from the survey about general user expectations</td>
</tr>
<tr>
<td>Operation</td>
<td>Operational data (e.g. Current vehicle location, data about orders)</td>
</tr>
<tr>
<td>Planned mobility service</td>
<td>Output of planning functions</td>
</tr>
</tbody>
</table>

Data groups
operative planning is persistent process

dynamism of planning functions approximates the dynamism of operational functions
Operation

- highly automated functions – humans are supervisors
Service management:
Vehicle checking
• checking general attributes (e.g. level of status) - select potential vehicles

Demand-capacity assignment
• comparing current attributes of travellers and vehicles - select the vehicle
• iteration: ordering-demand capacity assignment
• passengers are informed

Route planning
• planning useful and empty runs
• based on historical, current and forecasted data
• by the mobility management centre
• iteration: demand-capacity assignment-route planning; redistribution-route planning

Monitoring
• monitoring vehicles and sections of runs
• managing unexpected situations – automatic but human attendance is required

Redistribution
• leading the vehicles to charing, parking spot or high demand zone

Charging
• smart technology (reservation, identification, payment)
• automatized process – to avoid human acts

Repair/maintenance
• constantly monitored vehicles – vehicles provide data
• managed by the operators and mobility management centre
• quick automatic re-disposition

Service analysis
### Passenger handling

<table>
<thead>
<tr>
<th>Function</th>
<th>Sub-function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infotainment</td>
<td>Information about general conditions and supplementary services</td>
</tr>
<tr>
<td></td>
<td>Information about current situation</td>
</tr>
<tr>
<td></td>
<td>Journey planning and guiding/navigation</td>
</tr>
<tr>
<td></td>
<td>Information provision by devices in the stop</td>
</tr>
<tr>
<td></td>
<td>Information provision by onboard devices</td>
</tr>
<tr>
<td></td>
<td>Information provision by individual’s device</td>
</tr>
<tr>
<td></td>
<td>On board complaining/ request information</td>
</tr>
<tr>
<td></td>
<td>Route modification</td>
</tr>
<tr>
<td></td>
<td>Communication between vehicle-passenger</td>
</tr>
<tr>
<td>Entertainment</td>
<td></td>
</tr>
<tr>
<td>Complaining</td>
<td></td>
</tr>
<tr>
<td>Lost and found</td>
<td></td>
</tr>
<tr>
<td>Crowdsourcing</td>
<td></td>
</tr>
<tr>
<td>Ordering</td>
<td>Demand announcement (seat-reservation)</td>
</tr>
<tr>
<td>Management of entitlement</td>
<td>‘ticketing’</td>
</tr>
<tr>
<td></td>
<td>Boarding (authentication)</td>
</tr>
<tr>
<td></td>
<td>Alighting</td>
</tr>
<tr>
<td>Payment</td>
<td>Withdrawal</td>
</tr>
<tr>
<td>Management of cabin conditions</td>
<td>Management of comfort</td>
</tr>
<tr>
<td>Safety/Security</td>
<td>Avoiding accidents</td>
</tr>
<tr>
<td></td>
<td>Handling boarding (warning, open/close doors)</td>
</tr>
<tr>
<td></td>
<td>Handling passengers in incidents (diseased conditions, emergency situations, failures)</td>
</tr>
<tr>
<td></td>
<td>Life and property protection</td>
</tr>
<tr>
<td></td>
<td>Emergency call</td>
</tr>
</tbody>
</table>

more automatized passenger handling functions
Infotainment
• automatic, customized, personalized information provision – mobile application based
• before: obtain general information about service
• on-board: travel-related, real-time information
  interactive touchscreen-based entertainment
• feedback
• lost luggage and belongings – automatic detection

Ordering
• mandatory advance ordering via application
• customization, based on real-time data

Management of entitlement
• authentication (touchless, virtual/tracking the traveller)
• opening the vehicle/boarding

Management of cabin conditions
• conditions are monitored constantly
• management – automatically, self-adjusted

Safety/security
• security: CCTV surveillance - automatic image detection
• safety: V2N communication; sensor detection
• emergency call can be replaced by automatic detections
• remote monitoring by humans + fast moving teams

Payment
• price calculation – considering current travel data, dynamic price factors (traffic, sharing, demand), discounts,
• mobile payment, automatic payment (based on location), monthly withdrawal
Personnel of the future public transportation
• supervision of the automated functions
• aided by machines
• number of humans max decline

• operation process are more efficient
• personal interactions are needed in the case of special passenger groups and situations
• types: dispatchers, supervisors, customer service, security team rescue team

Task of mobility management centre in detail
• handling user data and travel parameters,
• providing personalized information,
• organizing the processes, calculating routes,
• controlling the processes (e.g. coordination of demands and capacities, timing of maintenance, booking of charging point), sending dispositions,
• fare calculation, managing payment process,
• evaluating the service and quality assessment.
Complex automation levels of public transportation

- considering: process planning and management, control (vehicle, fleet, traffic), passenger handlings functions

- aims:
  - describe a mobility service in a complex way
  - define the development potentials

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Description</th>
<th>Entity making decisions and executing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</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>2</td>
<td>Machine assistance</td>
<td>The human work is supported by the machine. However, the role of human is rather significant.</td>
<td>Human aided by machine</td>
</tr>
<tr>
<td>3</td>
<td>Partial automation</td>
<td>A significant part of the processes is executed by the machine. The human personnel monitor the processes.</td>
<td>Rather machine with human confirmation</td>
</tr>
<tr>
<td>4</td>
<td>Full automation</td>
<td>Processes are completely operated by a machine in an automatic way, the personnel attends as a supervisor.</td>
<td>Machine</td>
</tr>
</tbody>
</table>
- increasing demands
  - new user groups
  - total utility if travel increase
  - more and longer travels
- new, shared mobility forms
  - number of vehicles and size of vehicles decrease
  - empty vehicle runs increase
  - run mileage increase
  - daily performance increase
  - capacity utilization increase
- traffic parameters improve
  - headway decreases (platooning), speed increases
- less accident → less injury
- land use improve
  - less lanes, parking spaces
  - more charging points
- environmental load decrease

**Legend:**
- ↓ decrease
- ↓ significantly decrease
- ↑ increase
- ↑ significantly increase

**Favourable alteration**
- Environment: energy consumption, environmental impacts
- Mobility: vehicle utilization (sharing), beneficial vehicle run distance
- Society: number of traveller, number of travel, average length of travel, travel time, total utility of travel
- Traffic: headway, speed, accident
- Vehicle: vehicle size, vehicle number
- Infrastructure: road capacity, parking capacity, charging points
transitional periods (mix traffic)
- in automatization levels
- in traffic flows – proportion of AVs, proportion of different type of AVs -scenarios

modal share alteration
- individual car use and ownership decrease
- willingness to shift

Alteration in modal share in Budapest according to the willingness to shift based on survey; other impacts (e.g. promotion of soft mobility modes) were neglected.
land use:
• strict boundaries between infrastructure elements diminish
• less space is necessary for road traffic
• number road signs/markers decrease/alter

BUT! soft mobility modes

• shared road elements:
  • shared parking lots (Park and Charge, Load and Charge)
  • shared traffic lanes: in the peak hours for moving traffic, in the off-peak hours for parking

altering urban environment,
livable cities
share of traveller types

total individual utility of travelling is increasing
- useful activities during travel
- infotainment
Importance of required human abilities are altering

- mobile application related abilities increase
- detection and process information of other’s behaviour reduce
- cognitive capability reduce

Legend: abilities currently abilities in future
- slightly important
- very important
- incredibly important
- not important
information management is different according to modes
Challenges

user acceptability

SAFETY
• improving traffic safety, less accident, new insurances
• 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?

communication technology (hacking)
### Socioeconomic benefits
- reason of automation
- motivation: potential of significant cost-efficiency
- improvement: adequate management, control procedures

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Direct economic benefits</th>
<th>Social/passenger benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Reduction of number and severity of accidents</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of injuries within vehicles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less insurance-related activity and cost</td>
<td></td>
</tr>
<tr>
<td>Traffic</td>
<td>Higher capacity of existing infrastructure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Application of optimal speed profile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improvement of public transportation priority</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Shifting to alternative fuels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of energy consumption and emission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of noise emission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased passenger number, Reduction of private traffic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less parking space, more efficient land use and Altering urban patterns</td>
<td></td>
</tr>
<tr>
<td>Mobility service (operation)</td>
<td>Capacities and demands are coordinated better</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improved efficiency of operator’s decisions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elimination of driver timing problem</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reallocation of personnel efforts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better maintenance operations</td>
<td></td>
</tr>
<tr>
<td>Society (passengers)</td>
<td>Introduction of new mobility service concepts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shorter travel times</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better accessibility of public transportation both in space and time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improved management of transfers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Higher passenger satisfaction</td>
<td></td>
</tr>
</tbody>
</table>