Implications of Automation on Parking, Curb Space, and Urban Goods Delivery

Matthew Roorda
Canada Research Chair,
Freight Transportation and Logistics

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute
Presentation Outline

1. Overview of the Broad Research Program

2. Overview of Recent Relevant AV Research
   1. Designing Parking Facilities for Automated Vehicles
   2. Commercial Vehicle Deliveries with Robots/Drones

3. Proposed iCity CATTS research
   1. Parking / curbside management
   2. Freight Deliveries
Recent Research Focus
Prof. Matthew Roorda

- Freight and Logistics
- Parking
- Curbside Management
- Complete Streets
- Traffic Simulation and Modelling
- Vehicle Automation
Designing Parking Facilities for Automated Vehicles

- A typical vehicle spends 95% of its lifetime in a parking spot. (Mitchell, 2015)
- In the US approximately 6,500 sq miles of land is dedicated to parking (Chester et al. 2011, Thompson, 2016)
- In Hong Kong the average cost of one parking space is $180,000US (South China Morning Post, 2015)
- A survey of 20 cities around the world reported that drivers spend 20 minutes on average to find parking (Gallivan, 2011)
In a recent survey in 10 countries, 44% of the respondents reported that the biggest benefit of AV technology is its self-parking capability (World Economic Forum)
AV Parking Considerations

- Parking lots may no longer need to be located near driver destinations, due to AV self parking capability.
- Potential to locate parking lots at locations with lower land value.
- This may come at the expense of increased congestion due to zero occupancy vehicles.
- How to best design AV parking lots
Conventional Vehicle Parking

(a)
Autonomous Vehicle Parking

2 m²/veh savings per spot because of narrower driving, elevators and staircases become obsolete, and no space needed to open a vehicle’s doors.
Optimal Parking Facility Design

1-Optimal Parking Facility Layout
2-Optimal Allocation of Vehicles to Spots
3-Optimal Vehicle Relocation Policy
Relocation Policy

Any vehicle can be discharged at any time.

This requires space in the aisles to store “blocking” vehicles.
Vehicle Relocation in Larger Islands
Expected Relocations Per Vehicle Retrieval

\[ E[R] = \sum_{i=1}^{S} \sum_{v=0}^{x_i} \frac{d_i}{2yD} P_{iv}(d_i) R_v. \]

\[ P_{iv}(d_i) = \frac{(d_i/2y)^v / v!}{\sum x_i (d_i/2y)^t / t!} \]

\[ R_v = \frac{1}{v} \left[ \sum_{a=1}^{v} a + \sum_{a=1}^{v} (a - 1) \right] = \frac{1}{v} \left[ \frac{v(v + 1)}{2} \right] + \frac{(v-1)v}{2} = v \]
Impact of Demand on Optimal Layout

Supply

660 spots

$D=600$

$D=680$

720 spots

$D=640$

$D=720$

780 spots

$D=760$

$D=780$
Plot Shape Analysis

Testing of different parking lot dimensions shows that square shaped lots have the greatest capacity.

Capacity 540
Capacity 560
Capacity 500
Measures of effectiveness

Accommodating Vehicle Demand

Increasing Capacity vs Conventional

Percent of Area used for Parking

Minimizing Movement of Vehicles

(a) (b) (c) (d)
Some key conclusions

a) Square lots can accommodate the maximum parking demand

b) The maximum proportion of floor area for parking spaces is about 80% (20% of floor area needs to be used for clearance lanes)

c) A well designed AV parking lot can handle 65% to 85% more vehicles than a traditional parking lot on the same area.

d) As you near the maximum capacity, the number of relocations increases
Recent/Current Research on Urban Logistics

- Off-peak delivery pilot program in the Region of Peel
- Evaluation of City Logistics Concepts including:
  - Pack stations
  - Walk/cycle networks in downtown Toronto
  - Mobile distribution centres
Commercial Vehicle Deliveries with Robots/Drones (Paul Deng, MASc)

1. RACK FEEDER
   Transfers parcels to the integrated drones and the deliverer. Controlled via IT-based backend processes.

2. DRONES
   Fly autonomously on flight routes predefined by the system. Payload 2 kg, delivery radius 10 km, four propellers each measuring 21.5 inches in diameter.

3. MODULAR BATTERY SYSTEM
   Adaptable to the individual application in order to achieve the best possible proportion of weight and range.

4. E-DRIVE
   Locally emission-free and virtually silent. 75 kW permanent system performance, 270 Nm torque, a range of up to 270 km.

5. RACKING SYSTEM
   Lightweight racks made of carbon with load partitions made of aluminum sheet, adapted to the contours of the vehicle.
Commercial Vehicle Deliveries with Robots/Drones  (Paul Deng, MASc)
Objective
- Evaluate truck travel savings in urban areas by deploying delivery drones/robots from trucks to assist in deliveries.
Remaining Challenges

- Complex operations research problem
- Solvable heuristic solutions required
- Implications of delivery robots/drones operating in busy urban areas
- Customer interactions with robots
- Other technological options are arising
Summary of Proposed Research in the iCity CATTS Project

- **Urban Freight Automation**
  - Predicting the operations of new ‘modes’ of urban automated vehicle deliveries
    - Delivery robots, Drones, Driverless vehicles, Platooned trucks, Crowdsourcing in personal AVs
  - Incorporating these AV delivery scenarios in the Aimsun simulation model
  - Evaluating impacts
  - Identifying infrastructure policy needs to best prepare
    - Specialized delivery zones, delivery robot lanes, sidewalk use policy, transfer areas
Summary of Proposed Research in the iCity CATTS Project

- **Urban Freight Automation**
  - Predicting the operations of new ‘modes’ of urban automated vehicle deliveries
    - Delivery robots, Drones, Driverless vehicles, Platooned trucks, Crowdsourcing in personal AVs
  - Incorporating these AV delivery scenarios in the Aimsun simulation model
  - Evaluating impacts
  - Identifying infrastructure policy needs to best prepare
    - Specialized delivery zones, delivery robot lanes, sidewalk use policy, transfer areas
Summary of Proposed Research in the iCity CATTS Project

- Urban Freight Automation
  - Predicting the operations of new ‘modes’ of urban automated vehicle deliveries
    - Delivery robots, Drones, Driverless vehicles, Platooned trucks, Crowdsourcing in personal AVs
  - Incorporating these AV delivery scenarios in the Aimsun simulation model
  - Evaluating impacts
  - Identifying infrastructure policy needs to best prepare
    - Specialized delivery zones, delivery robot lanes, sidewalk use policy, transfer areas
Summary of Proposed Research in the iCity CATTS Project

- Understanding passenger AV parking needs
  - Evaluating demand for MaaS and AVs in urban areas
    • Gaming approaches to data collection, stated preference
  - Translating this demand into parking, drop-off and pick-up demand
    • Scenarios based on survey results
  - Optimal parking facility location, and facility design
    • Minimize empty vehicle distance travelled, minimize traffic disruption
  - Assessment of curbside management strategies to best prepare
    • Curbside reservations, drop-off pick-up zones, zero-occupancy vehicle restrictions, pricing
Summary of Proposed Research in the iCity CATTS Project

- Understanding passenger AV parking needs
  - Evaluating demand for MaaS and AVs in urban areas
    - Gaming approaches to data collection, stated preference
  - Translating this demand into parking, drop-off and pick-up demand
    - Scenarios based on survey results
  - Optimal parking facility location, and facility design
    - Minimize empty vehicle distance travelled, minimize traffic disruption
  - Assessment of curbside management strategies to best prepare
    - Curbside reservations, drop-off pick-up zones, zero-occupancy vehicle restrictions, pricing
Summary of Proposed Research in the iCity CATTS Project

- Understanding passenger AV parking needs
  - Evaluating demand for MaaS and AVs in urban areas
    - Gaming approaches to data collection, stated preference
  - Translating this demand into parking, drop-off and pick-up demand
    - Scenarios based on survey results
  - Optimal parking facility location, and facility design
    - Minimize empty vehicle distance travelled, minimize traffic disruption
  - Assessment of curbside management strategies to best prepare
    - Curbside reservations, drop-off pick-up zones, zero-occupancy vehicle restrictions, pricing
Summary of Proposed Research in the iCity CATTS Project

- Understanding passenger AV parking needs
  - Evaluating demand for MaaS and AVs in urban areas
    - Gaming approaches to data collection, stated preference
  - Translating this demand into parking, drop-off and pick-up demand
    - Scenarios based on survey results
  - Optimal parking facility location, and facility design
    - Minimize empty vehicle distance travelled, minimize traffic disruption
  - Assessment of curbside management strategies to best prepare
    - Curbside reservations, drop-off pick-up zones, zero-occupancy vehicle restrictions, pricing
Questions!