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

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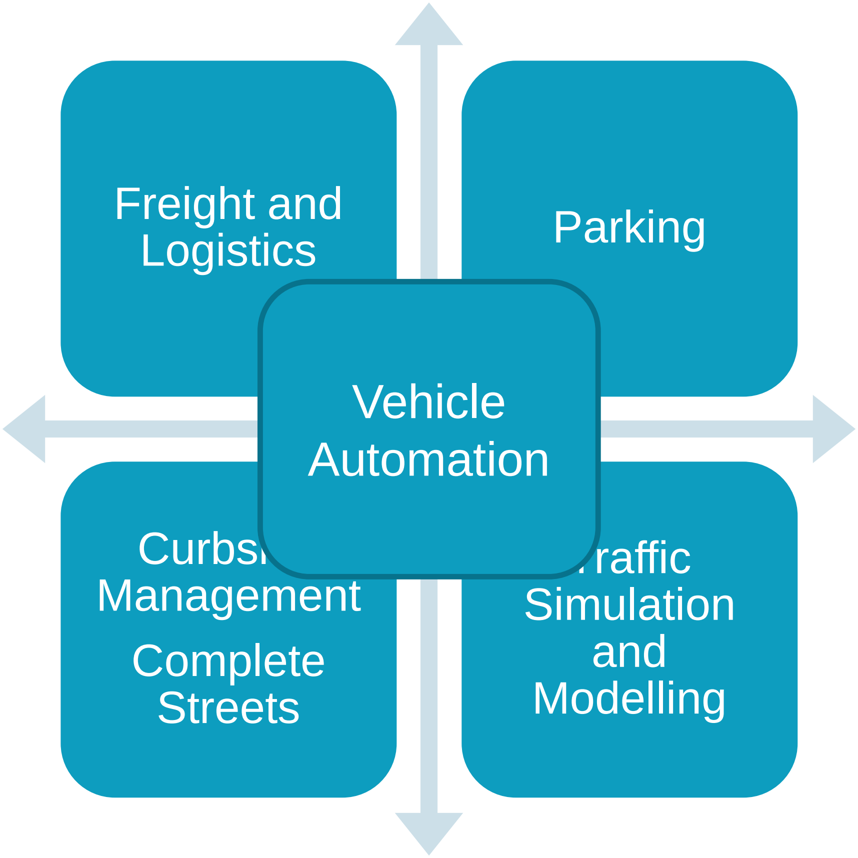
Presentation Outline

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

Vehicle Automation

Curbs
Management

Complete Streets

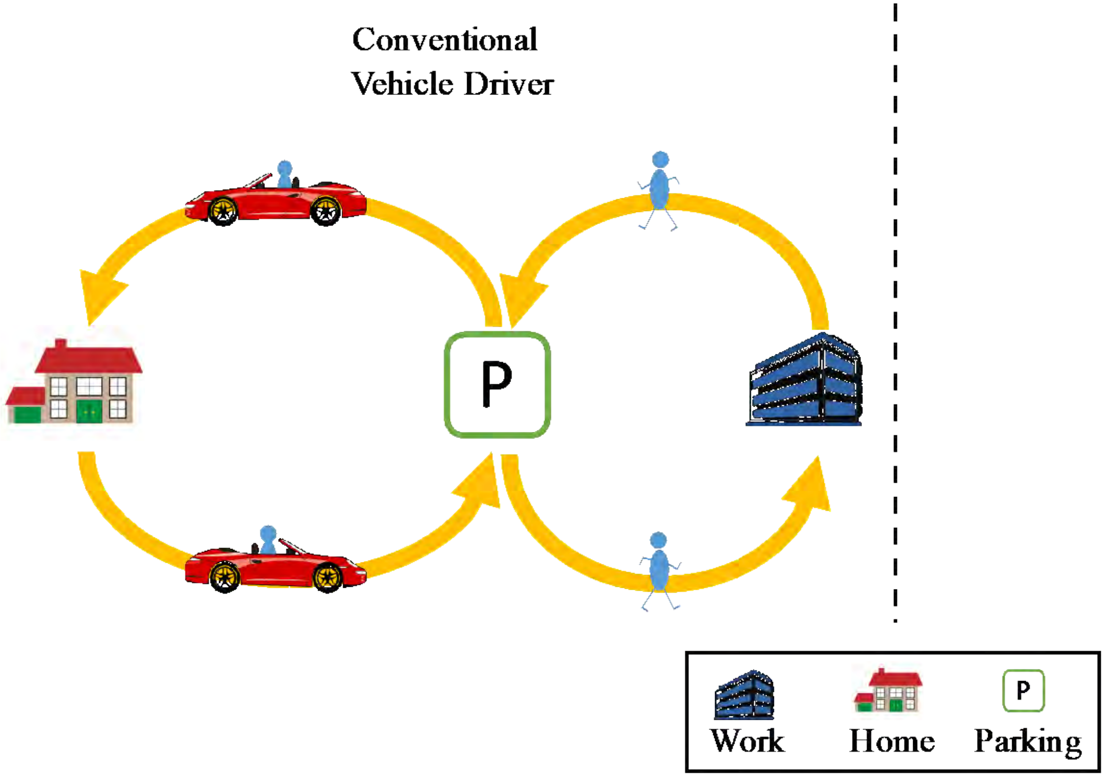
raffic Simulation and Modelling

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)

The Emerging Parking Pattern of Autonomous Vehicles

(Mehdi Nourinejad, PhD; Sina Bahrami, PhD)

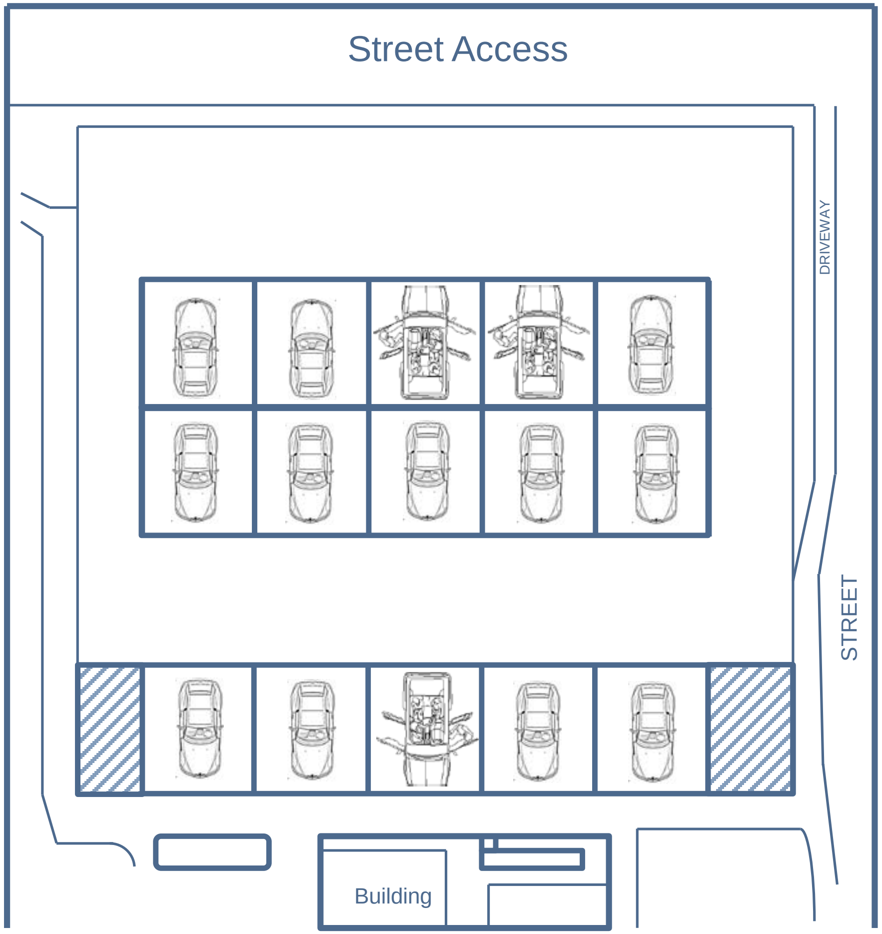


In a recent survey in 10 countries, 44% of the respondents reported that the biggest benefit of AV technology is its self-parking capability (World Economic Forum)

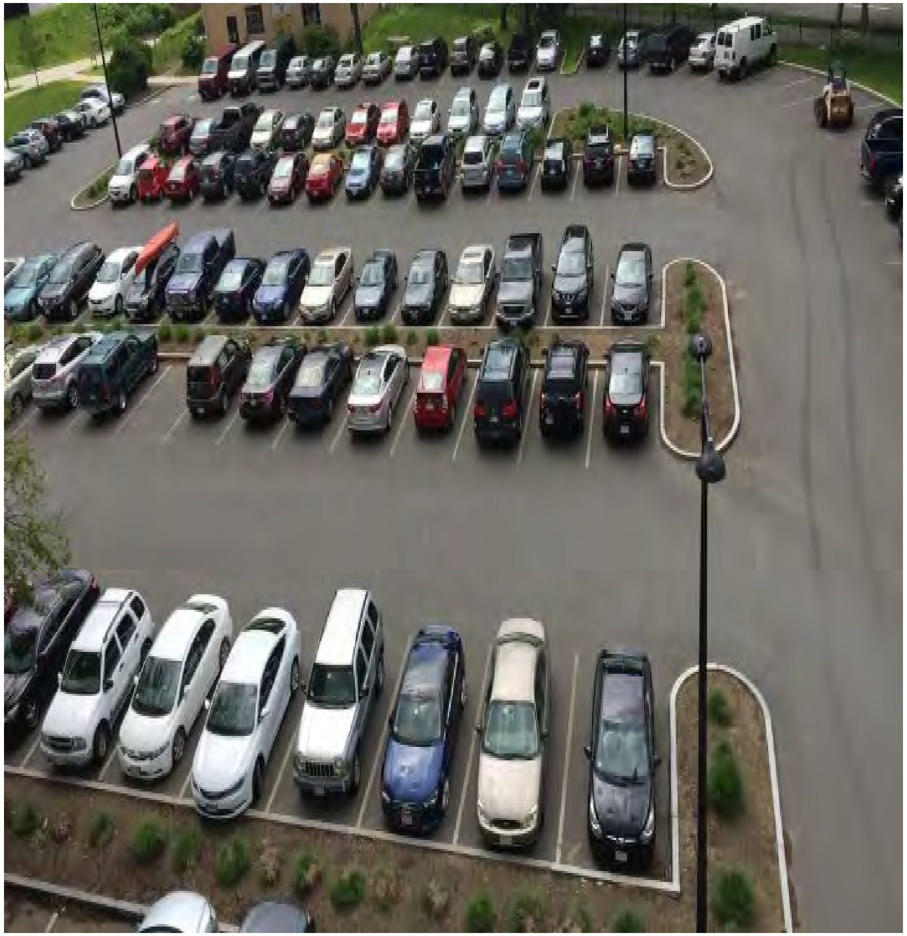
AV Parking Considerations

- 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

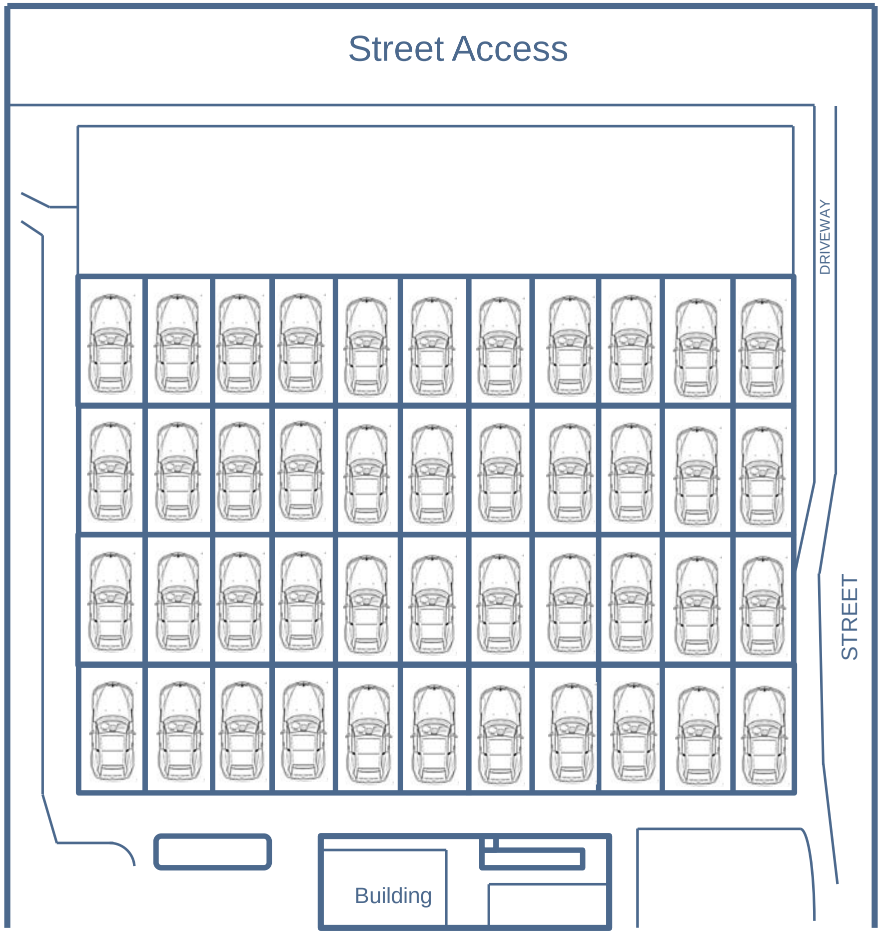
Conventional Vehicle Parking



(a)



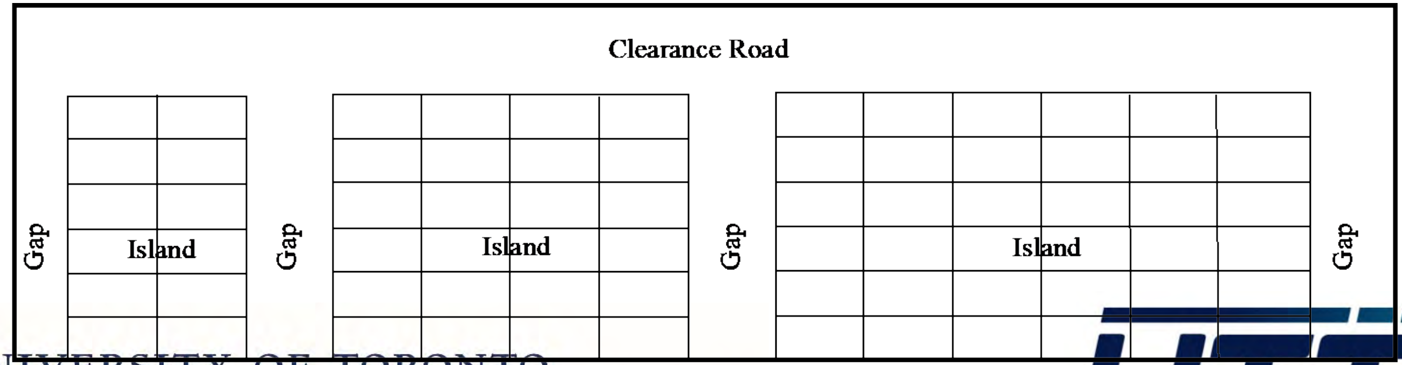
Autonomous Vehicle Parking



2 m^2/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

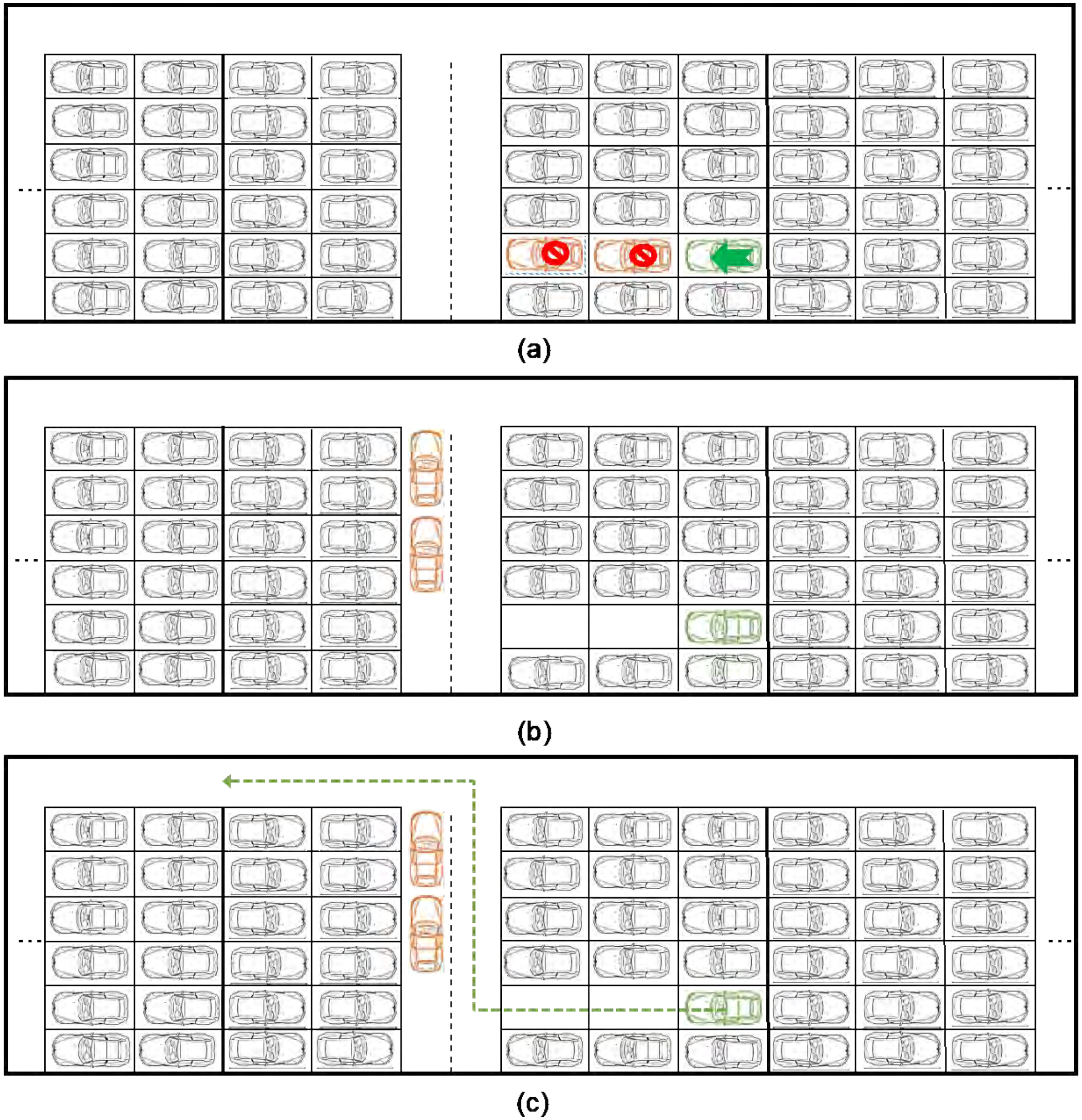
1-Optimal Parking Facility Layout
2-Optimal Allocation of Vehicles to Spots
3-Optimal Vehicle Relocation Policy



Relocation Policy

Any vehicle can be discharged at any time

This requires space in the aisles to store “blocking” vehicles

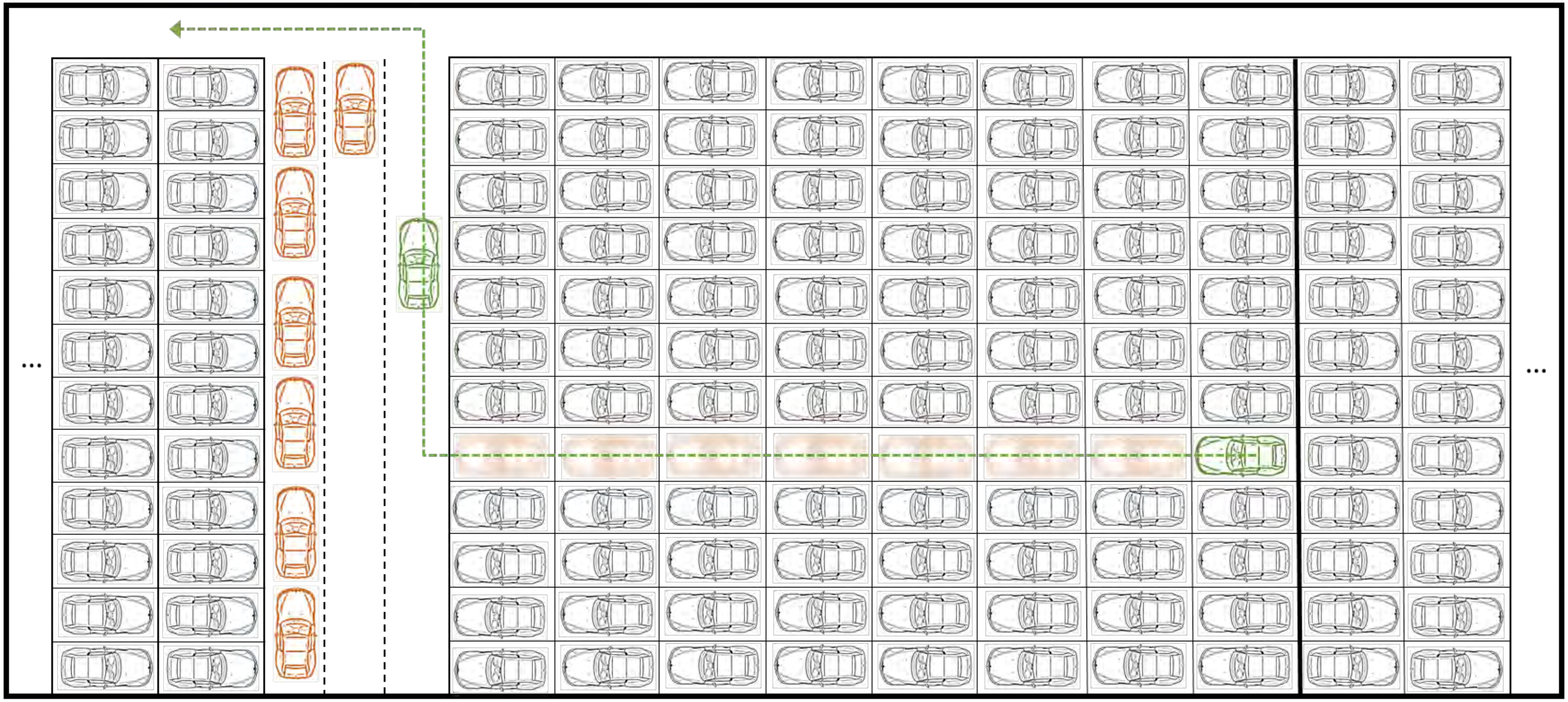


(a)

(b)

(c)

Vehicle Relocation in Larger Islands

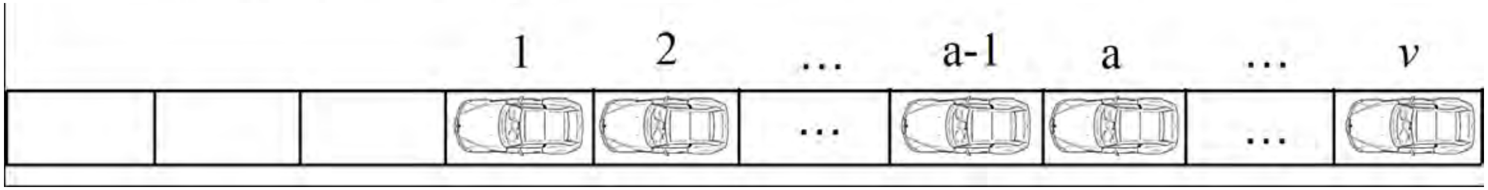


Expected Relocations Per Vehicle Retrieval

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

$$P_{iv}(d_i) = \frac{(d_i/2y)^v / v!}{\sum_{t=0}^{x_i} (d_i/2y)^t / t!}.$$

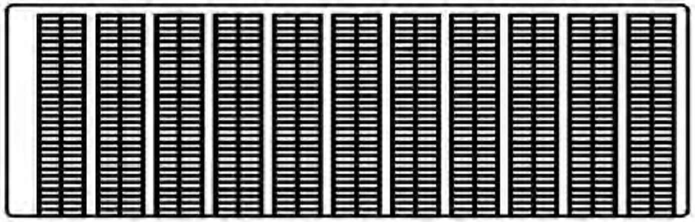
$$R_v = \frac{1}{v}\Big[\sum_{a=1}^{v} a + \sum_{a=1}^{v} (a-1)\Big] = \frac{1}{v}\Big[\frac{v(v+1)}{2} + \frac{(v-1)v}{2}\Big] = v$$



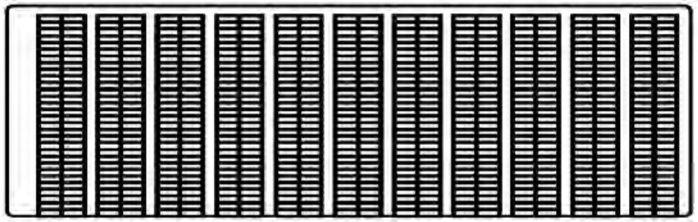
Impact of Demand on Optimal Layout

Supply

660
spots

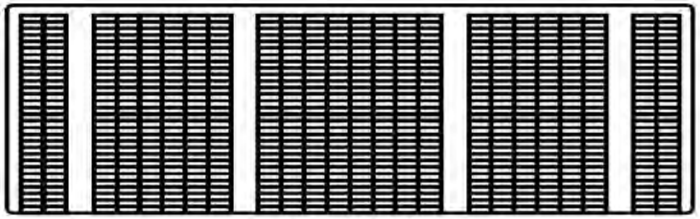


D=600



D=640

720
spots



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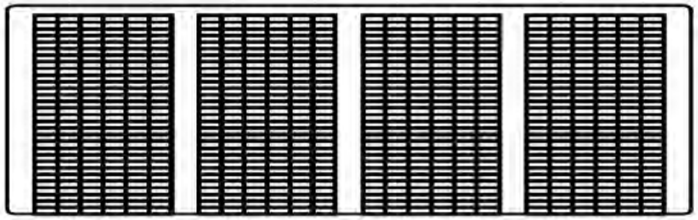
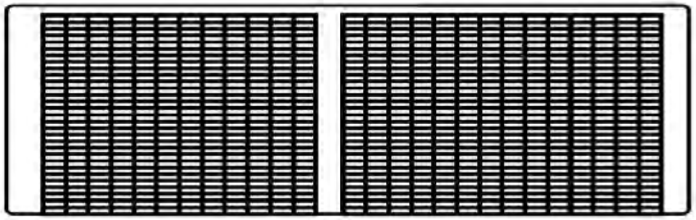


D=720

780
spots



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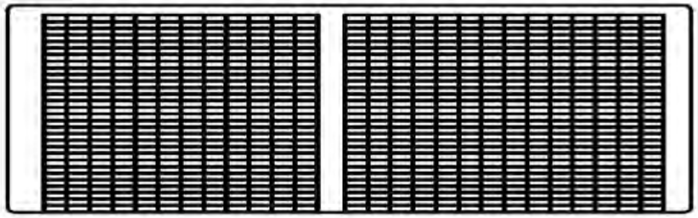

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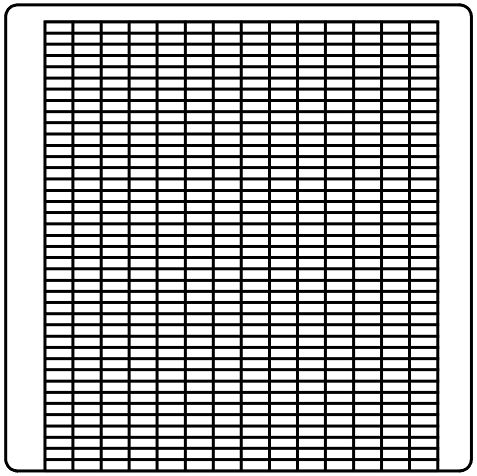
Plot Shape Analysis



Capacity
540

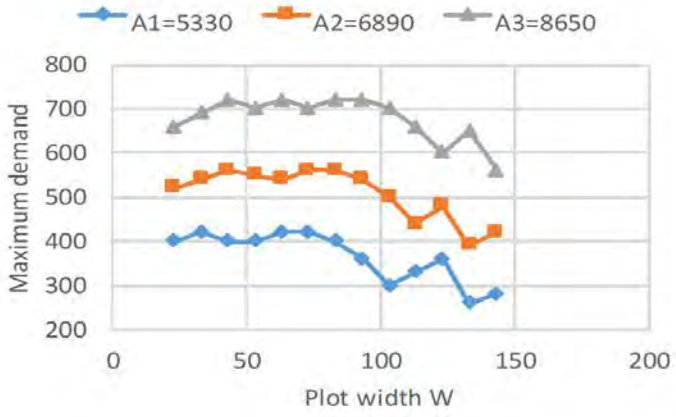
Capacity
560

Capacity
500

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

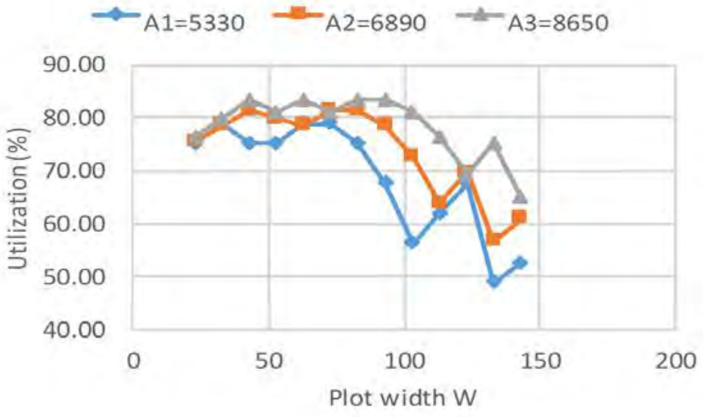
Measures of effectiveness

Accommodating Vehicle Demand



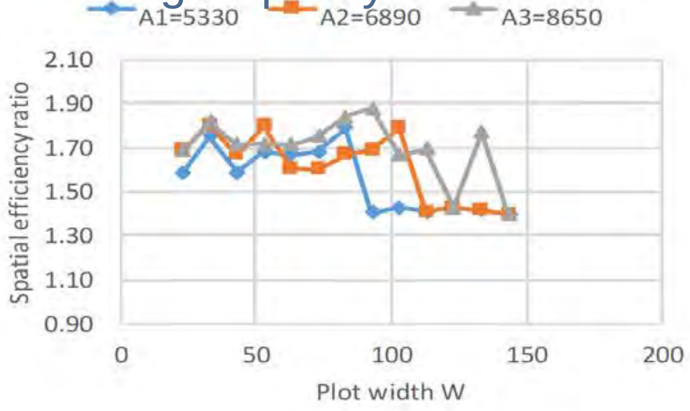
(a)

Percent of Area used for Parking



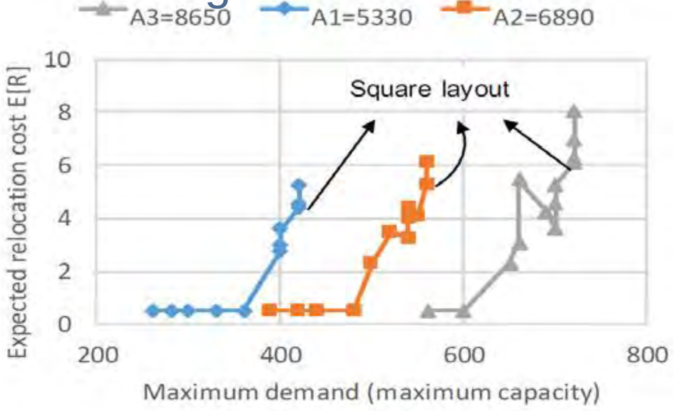
(b)

Increasing Capacity vs Conventional



(c)

Minimizing Movement of Vehicles



(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)

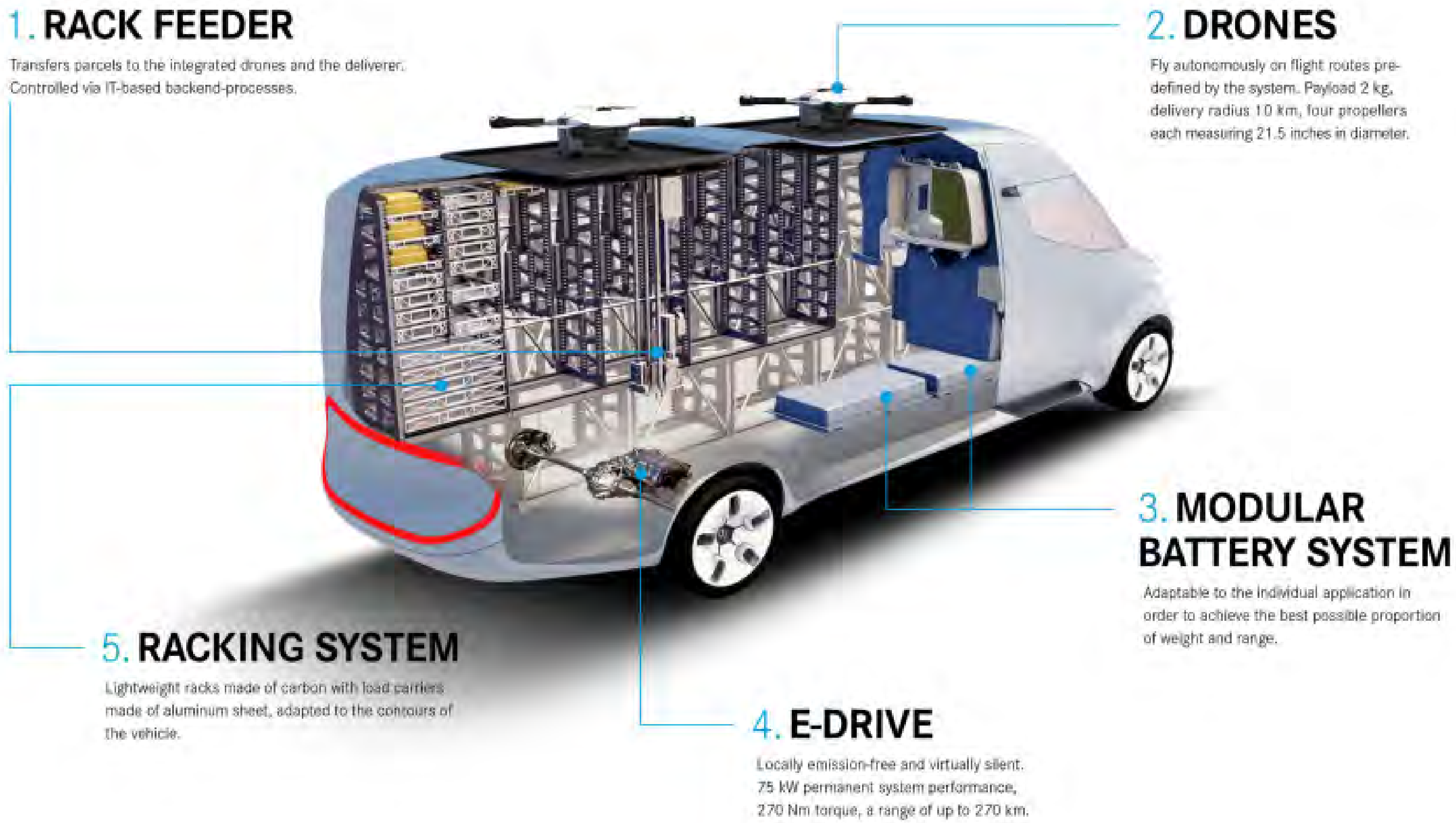
c)A well designed AV parking lot can handle 65% to 85% more vehicles than a traditional parking lot on the same area.

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 pre-defined 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

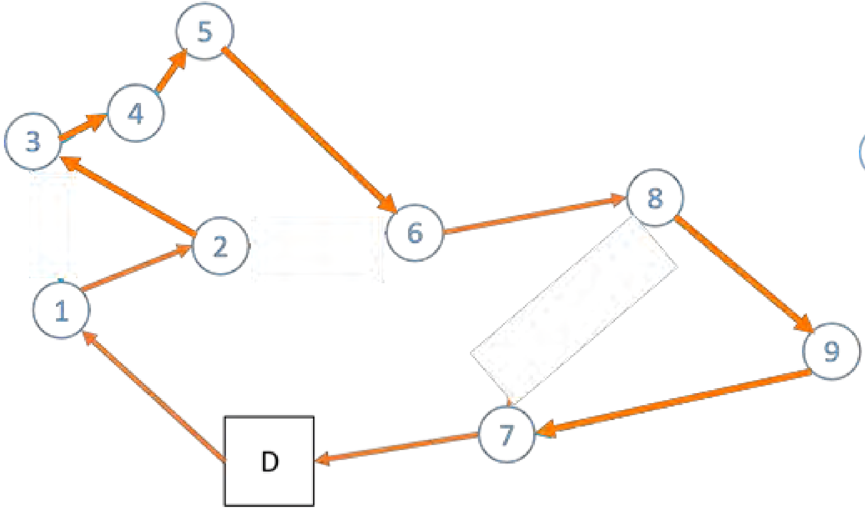
Lightweight racks made of carbon with load carriers made of aluminum sheet, adapted to the contours of the vehicle.

Commercial Vehicle Deliveries with Robots/Drones (Paul Deng, MASc)

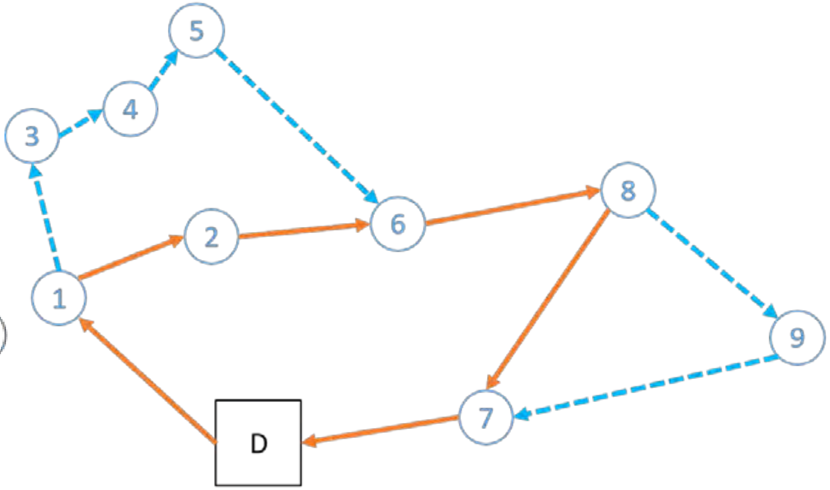
Commercial Vehicle Deliveries with Robots/Drones (Paul Deng, MASc)

- Objective
  - Evaluate truck travel savings in urban areas by deploying delivery drones/robots from trucks to assist in deliveries

Conventional



Proposed



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

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- 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

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Questions!