

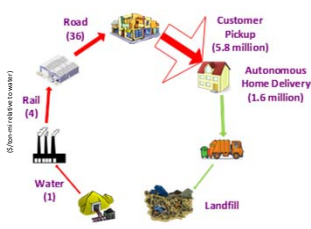
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- Objective:** Explore impact of autonomous/driverless vehicles on home delivery
- Hypothesis:** High labor cost of driver-based home delivery major reason for customer pickup at stores
- Methodology:** Propose design for public logistics network that would allow consolidated-load delivery to the home
- Results:** At scale, cost of on-demand driverless-based home delivery same as current driver-based delivery
- Conclusion:** Driverless-based home delivery can eliminate need for all non-recreational shopping, which is especially important for the disabled and elderly

### Dirt-to-Dirt Logistics Costs



### Home Delivery Alternatives

| Unloading at Home               | Point-to-Point On-Demand Delivery  | Multistop Delivery Window   |
|---------------------------------|--|---|
| Customer Supervised             | <ul style="list-style-type: none"> <li>Time-sensitive driver-based (pizza)</li> <li>Driverless vehicle (manual unloading)</li> </ul> | <ul style="list-style-type: none"> <li>Bulk-item driver-based (furniture, appliances)</li> </ul>  |
| Unattended (packaged/container) | <ul style="list-style-type: none"> <li>Aerial drone</li> </ul>   | <ul style="list-style-type: none"> <li>Time-insensitive driver-based (UPS, USPS, FedEx)</li> <li>Driverless vehicle (auto unloading)</li> </ul> |

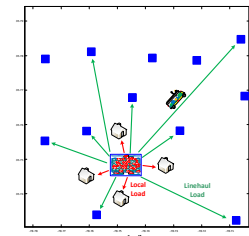
Amazon Drone  
\$1.00/delivery

Starship Delivery Robot  
\$1.99/delivery

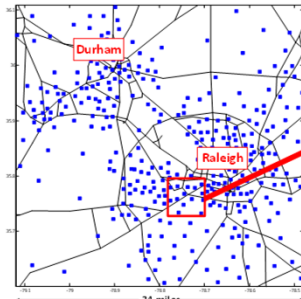
Nuro Delivery Vehicle  
\$/delivery NA

Delivery Vehicle with Auto Unloading  
\$3.50/delivery

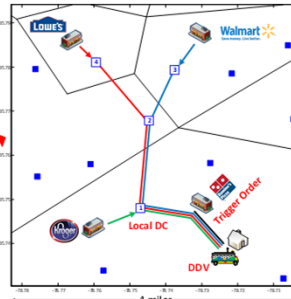
### Logistics Network for Consolidated-Load Home Delivery



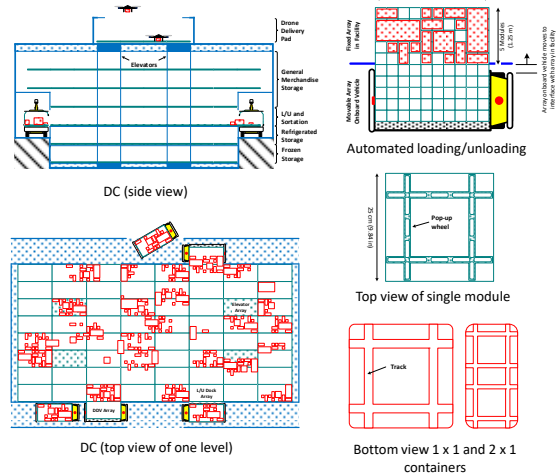
Local to home and linehaul loads to other DCs



DCs covering Raleigh-Durham metro area



Delivery of four orders to a home.



### Network Coordination: Develop mechanism to coordinate operation of each container, vehicle, and DC in the network

- Separate firm can own each DC and vehicle → coordination more difficult than private network
- Local load is a single shipment
- Containers in linehaul load part of different shipments each owned by a separate firm
- Containers pay DC for storage time

#### Example: 2-D Load Formation

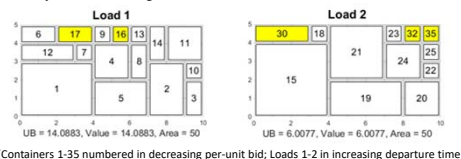
- Select Containers:** Sorted based on decreasing per-unit bid value; selected until cumulative area = 50 (capacity of module array)
- Order Containers:** Sequence based on length, width, bid; may not be feasible to fit (pack) all containers into array (bin)

| Cont. | Length | Width | Area | Cum. Area | Bid    | Per Unit Bid |
|-------|--------|-------|------|-----------|--------|--------------|
| 1     | 4      | 3     | 12   | 12        | 4.03   | 0.3361       |
| 2     | 2      | 3     | 6    | 18        | 1.99   | 0.3322       |
| 3     | 1      | 2     | 2    | 20        | 0.64   | 0.3195       |
| 4     | 2      | 2     | 4    | 24        | 1.27   | 0.3190       |
| 5     | 3      | 2     | 6    | 30        | 1.80   | 0.3000       |
| 6     | 2      | 1     | 2    | 32        | 0.56   | 0.2787       |
| 7     | 1      | 1     | 1    | 33        | 0.27   | 0.2737       |
| 8     | 1      | 2     | 2    | 35        | 0.54   | 0.2715       |
| 9     | 1      | 1     | 1    | 36        | 0.27   | 0.2650       |
| 10    | 1      | 1     | 1    | 37        | 0.36   | 0.2628       |
| 11    | 2      | 2     | 4    | 41        | 0.95   | 0.2379       |
| 12    | 3      | 1     | 3    | 44        | 0.55   | 0.1843       |
| 13    | 1      | 1     | 1    | 45        | 0.17   | 0.1750       |
| 14    | 1      | 2     | 2    | 47        | 0.35   | 0.1731       |
| 15    | 4      | 4     | 16   | 2.64      | 0.1651 |              |
| 16    | 1      | 1     | 1    | 48        | 0.15   | 0.1500       |
| 17    | 2      | 1     | 2    | 50        | 0.27   | 0.1366       |
| 18    | 1      | 1     | 1    | 51        | 0.12   | 0.1220       |

| Cont. | Length | Width | Bid  |
|-------|--------|-------|------|
| 1     | 4      | 3     | 4.03 |
| 5     | 3      | 2     | 1.99 |
| 12    | 3      | 1     | 0.55 |
| 2     | 2      | 3     | 1.99 |
| 4     | 2      | 2     | 1.27 |
| 11    | 2      | 2     | 0.95 |
| 6     | 2      | 1     | 0.56 |
| 17    | 2      | 1     | 0.27 |
| 3     | 1      | 2     | 0.64 |
| 8     | 1      | 2     | 0.54 |
| 14    | 1      | 2     | 0.35 |
| 7     | 1      | 1     | 0.27 |
| 9     | 1      | 1     | 0.27 |
| 10    | 1      | 1     | 0.26 |
| 13    | 1      | 1     | 0.17 |
| 16    | 1      | 1     | 0.15 |
| 18    | 1      | 1     | 0.12 |

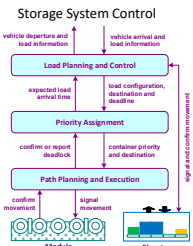
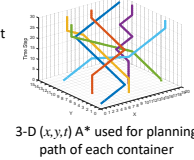
UB = 14.089

**Diseconomies of Scale:** Yellow containers spend/bid less on a per-unit basis to join a load leaving earlier due to their smaller size



### DC Storage Control:

- Module ≤ Container ≤ Shipment ≤ Load
- Each container assigned a unique priority that determines its planning sequence



### Example: Unloading and Loading Operations at DC

