Locating and Scheduling Inner-City Hubs for Last Mile Deliveries

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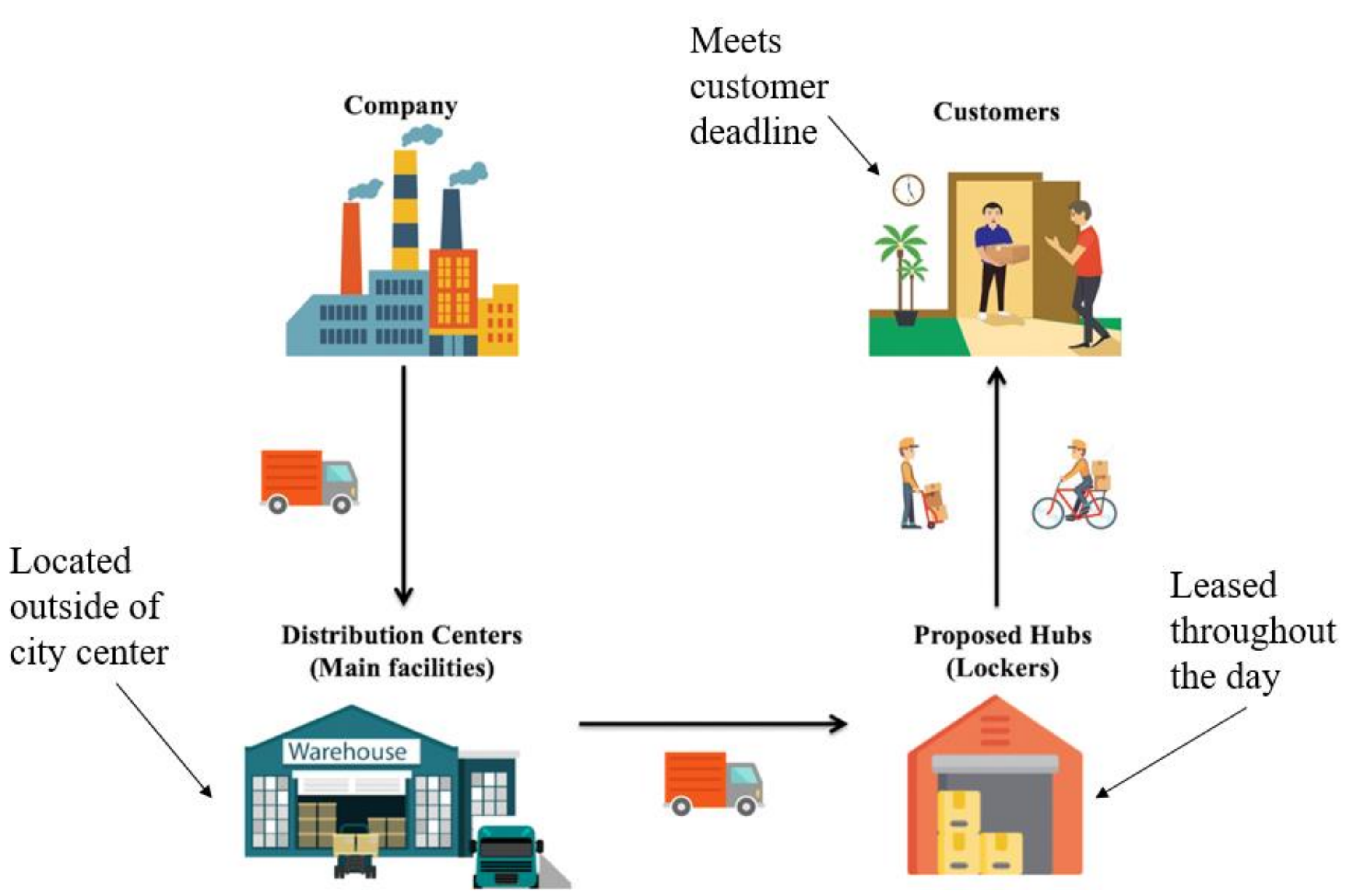
Motivation

- Problems with door-to-door last mile deliveries in dense urban areas (e.g. limited parking, congestion)
- Growing customer expectation of on-demand product delivery/service
- Emergence and potential of sharing economy for urban logistics (Flexe, Warehouse Exchange)

Objective

- Develop an alternative supply chain method of last-mile parcel delivery within dense urban areas which:
  - Is cost effective for companies
  - Meets customer deadline preferences
  - Reduces Vehicle Miles Traveled (VMTs) by trucks inside cities

Proposed Framework

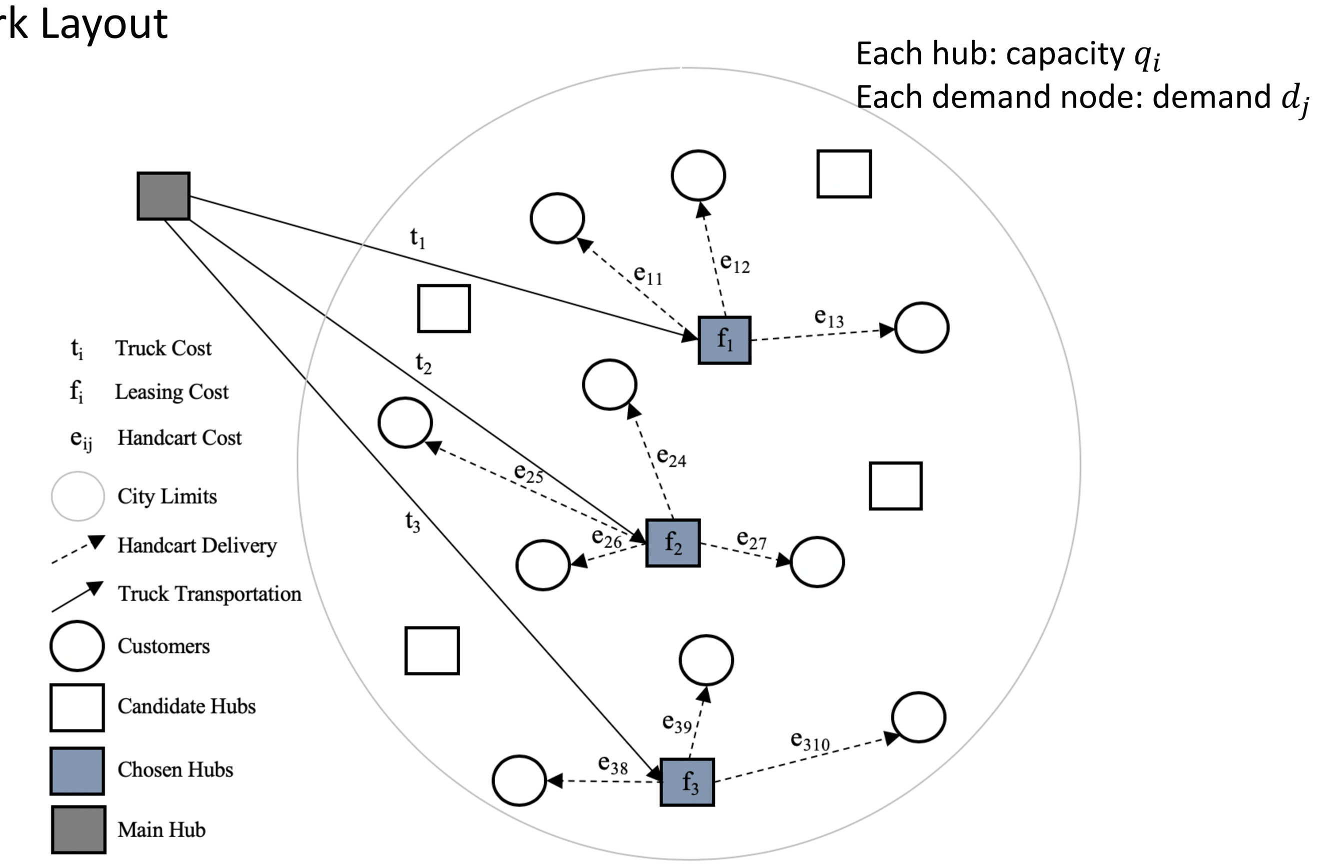


Problem Setting

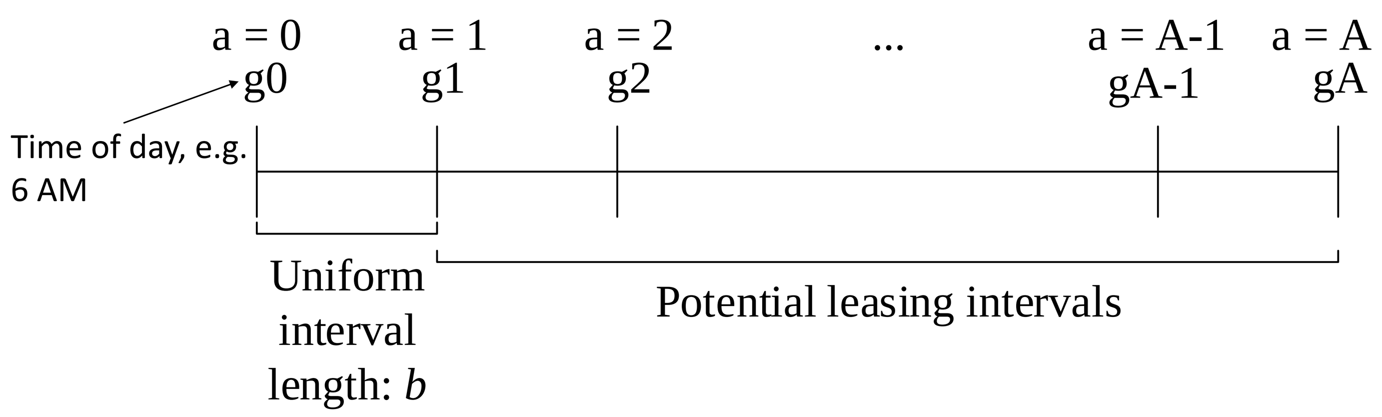
- Single company decides *when* and *where* to lease hubs throughout the day.
  - Long term decision – i.e. several month lease.
- Known information:
  - Facility locations, capacity, and leasing costs.
  - Customer locations, demand, and deadline requirements.
  - Vehicle capacities, average traffic speeds.

Modeling Framework

- Network Layout



- Time window framework



Model Formulation

- **Capacitated hub location/allocation/scheduling problem:**
- Decision variables:

$$X_i^a = \begin{cases} 1, & \text{if facility i is used in time period } a \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{ij}^a = \begin{cases} 1, & \text{if node j is allocated to facility i for time period } a \\ 0, & \text{otherwise} \end{cases}$$

- Objective:

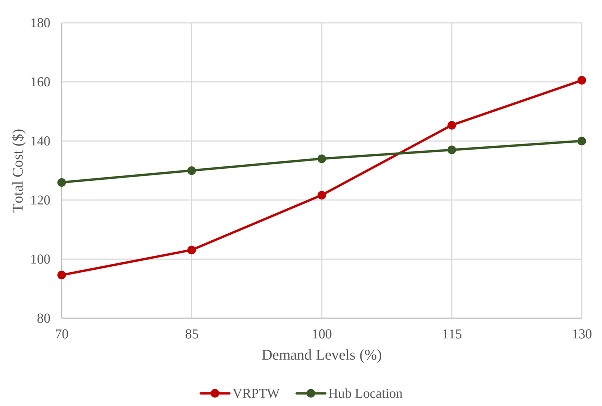
$$\min \sum_{a\in A-\{0\}} \sum_{i\in I} \left(X_i^a \left(t_i^a + f_i^a \right) \right) + \sum_{a\in A-\{0\}} \sum_{i\in I} \sum_{j\in J} e_{ij} Y_{ij}^a$$

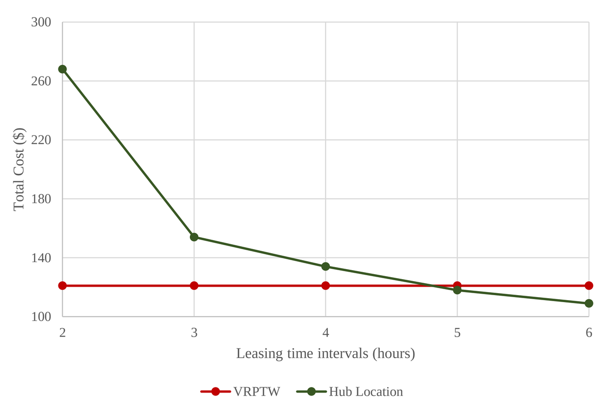
Transportation costs | Leasing costs | Handcart Delivery costs

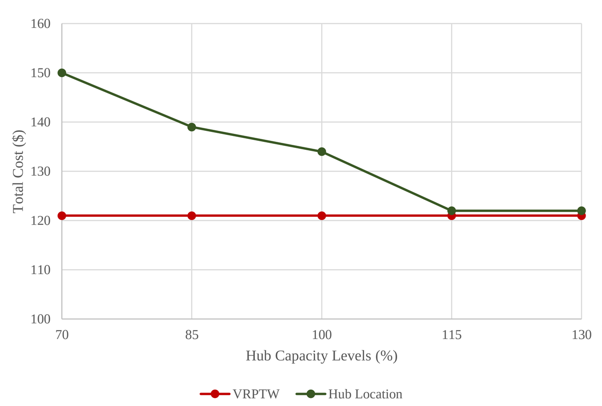
- Constraints:
  - Location/allocation constraints
  - Scheduling constraints
  - Integrality constraints

Numerical Experiments

- Implement proposed model within toy network using CPLEX
  - 10 candidate hubs, 20 customers, Leasing interval b = 4hrs
  - Exogenous leasing, transportation, delivery costs estimated from real-world data
- **Sensitivity analysis:** Compare solution of proposed model to state-of-practice door to door delivery mechanism (VRPTW) under a range of: i) demand levels; ii) Leasing interval durations; iii) hub capacities

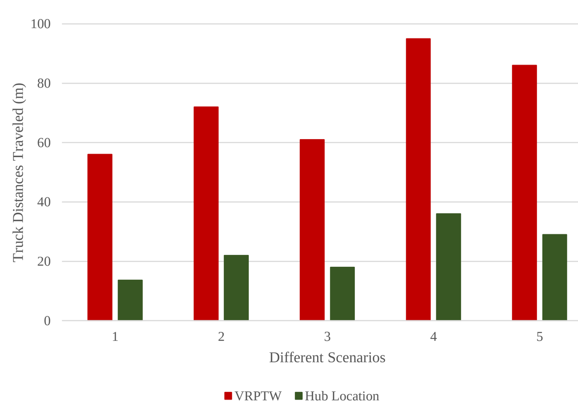






- When demand increases, the hub location model becomes cheaper than VRPTW.
- With larger intervals, more flexibility in the hub location model to deliver within the time deadlines.
- As the capacities increase, total cost for both models becomes approximately the same.

- **VMT Comparison:**



- Dramatic reduction in truck distances traveled when the hub location model is implemented across all different scenarios
- Average 60% lower distances traveled with hub location model.

Summary/Future Work

- Development of a mathematical model for the capacitated hub location problem with time deadlines and allocation distance constraints.
- Incorporate the aspect of leasing the hubs during daily time intervals, turning it into a location/allocation/scheduling problem.
- Sensitivity analysis shows scenarios where model is cheaper than (or equal to) state of practice door-to-door delivery: high demand, long leasing interval, high hub capacities
- Proposed model also reduces VMT
- Potential extensions: model incorporating behavior of multiple companies, alternative delivery methods (e.g. drone or robot), determining route for multiple deliveries

Contact

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