7 Sorting with robots: where to drop off the parcel?

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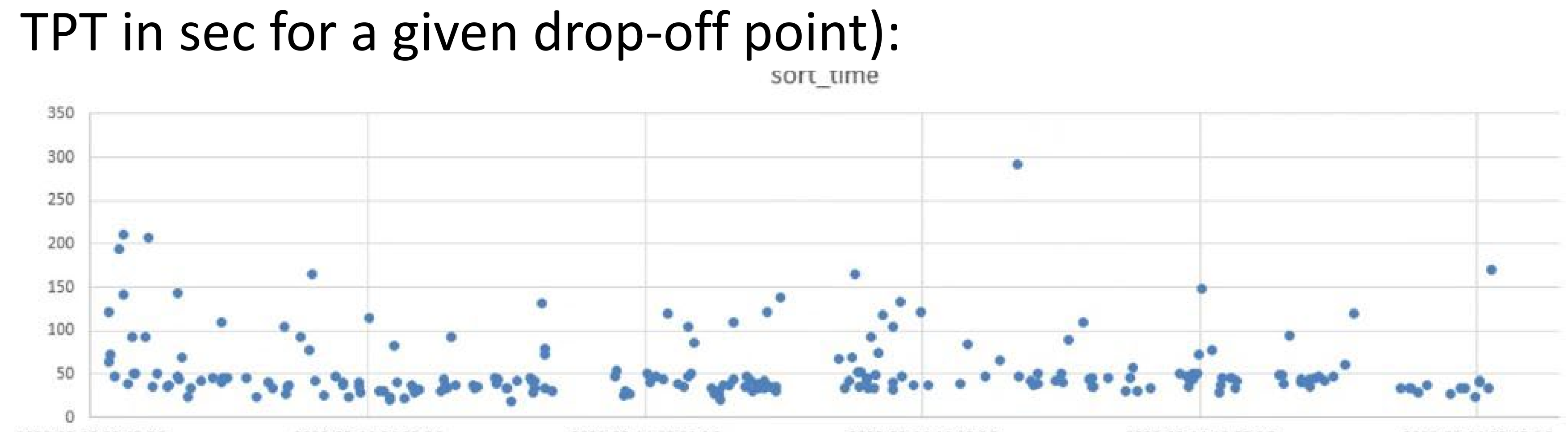
Objective

Assign destinations to drop-off points in Robotic Sorting System (RSS) to maximize throughput capacity, considering robot congestion.

Background

Sorting at Deppon

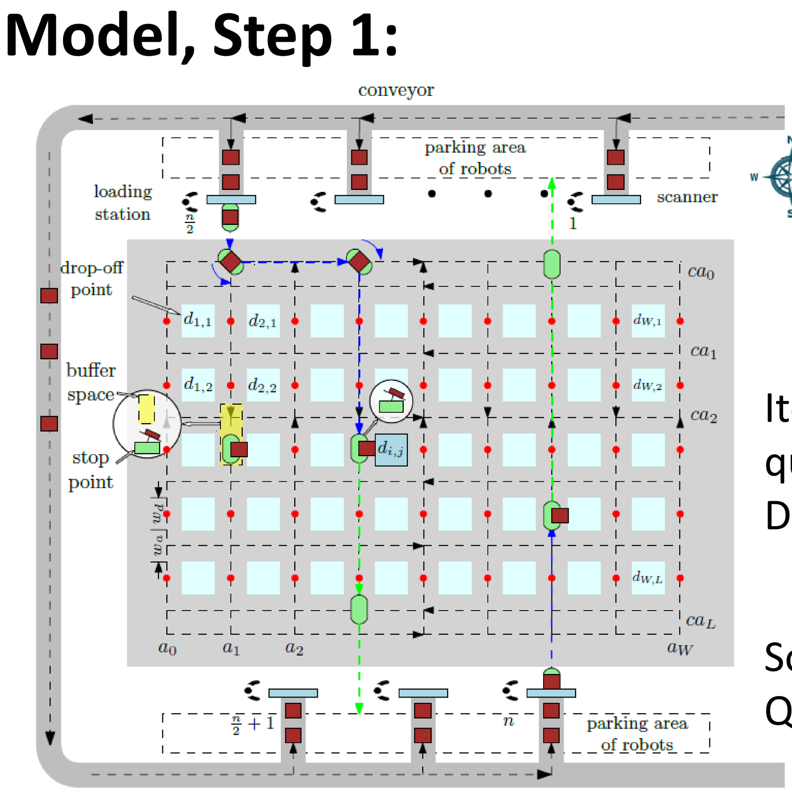
Sorting using an RSS can be cheaper than conventional sorters (e.g. tilt tray), because of smaller footprint and building. It is also more flexible (adding/removing destinations and robots). However, systems can be congested. See below (China Postal; TPT in sec for a given drop-off point):

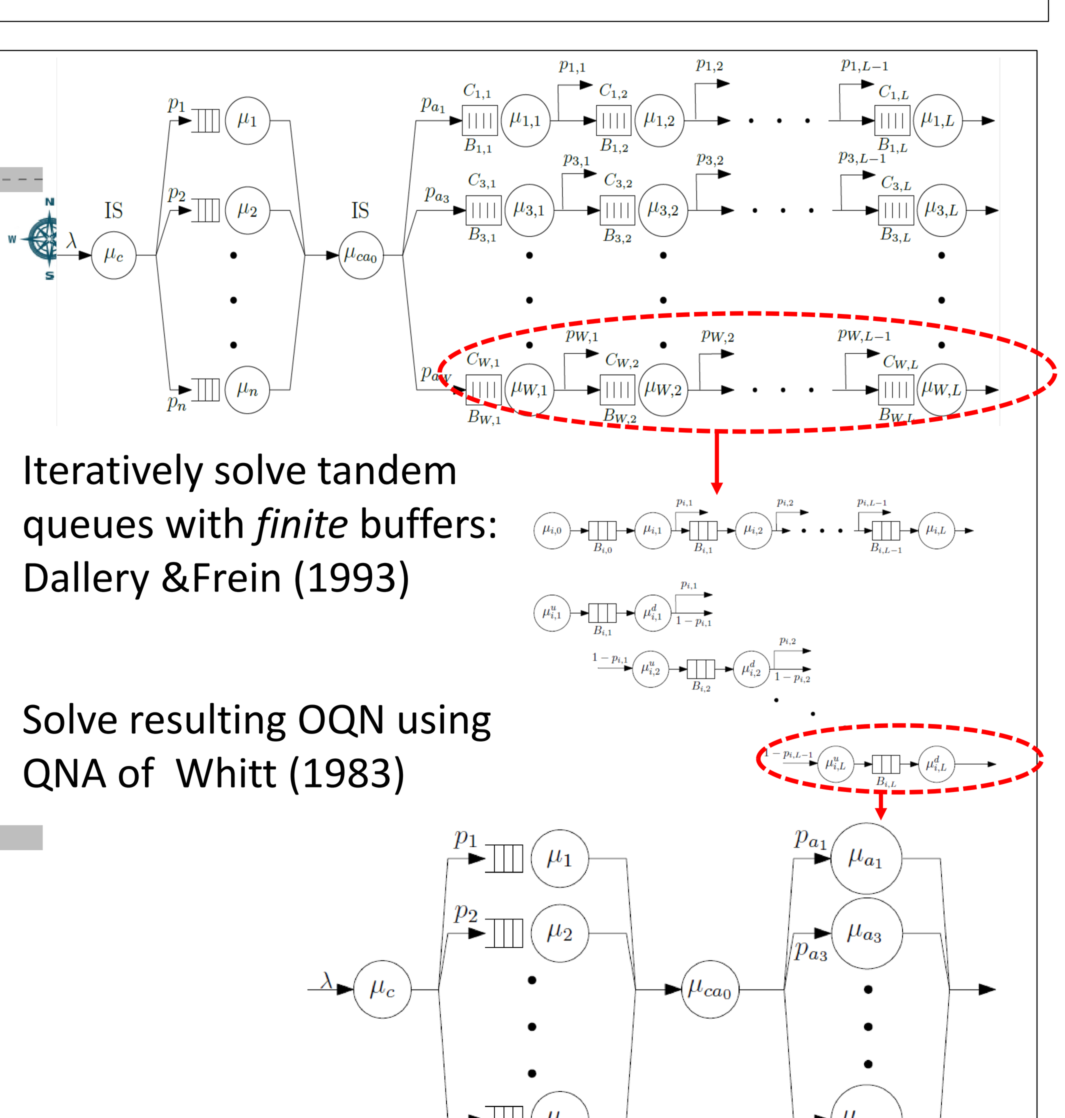


Methodology

Tools: 1) OQN model estimating *TT*, including congestion, for given assignment 2) use this in MIP to determine optimal assignment

Model, Step 1:





Result: $TT(\boldsymbol{x})$, with given assignment $\boldsymbol{x} = (x_{i,j}), i = 1,..,M, j = 1, \dots, N$:
Validation: errors <3%.

Model, Step 2, Optimize assignment

Min $TT(\boldsymbol{x})$

$$\sum_{j=1}^{N} x_{i,j} = 1, \qquad i = 1,..,M$$

$$\sum_{i=1}^{M} x_{i,j} = 1, \qquad j = 1,..,N$$

$x_{i,j}$ =1, if destination i is assigned to drop-off point j, 0 otherwise

For given assignment and buffer capacities.

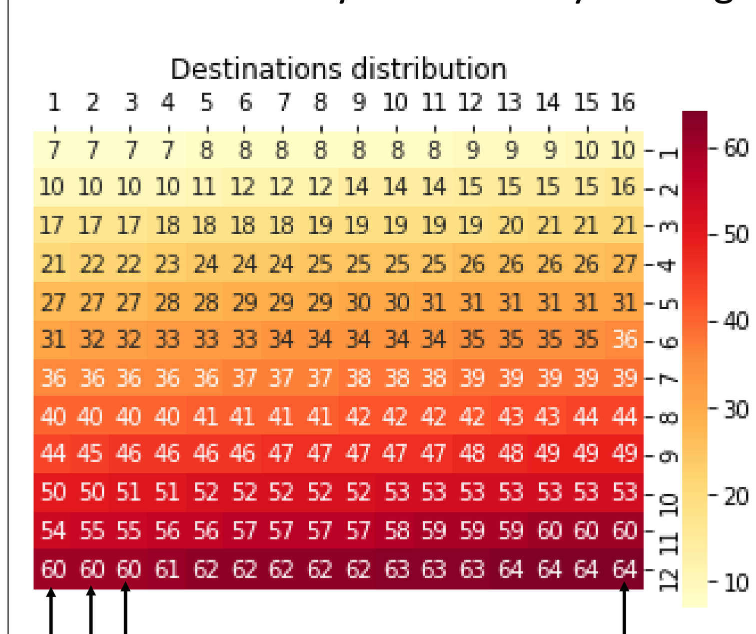
Assumption: $N = M = L \times W$

Solution: ALNS (Ropke& Pisinger, 2006)

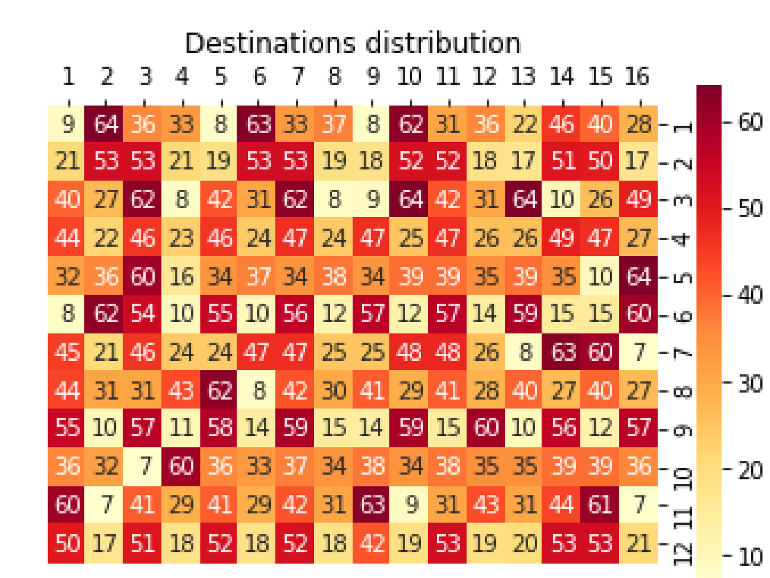
Results

Results 1: Optimize assignment at Deppon Express (Shanghai)

Data: 30 randomly selected days during 5 months from November 2018 to March 2019



current (HC)



optimized (ALNS)

Throughput time reduction: 25%, congestion time reduction: 73%

Develop assignment heuristic: BA (Balance destinations over drop-offs). ALNS is still significantly better

Results 2: Minimize cost, for given Throughput Capacity (TC) λ

$\min CT(n, R, p) = C_{ls} \cdot n + C_R \cdot R$

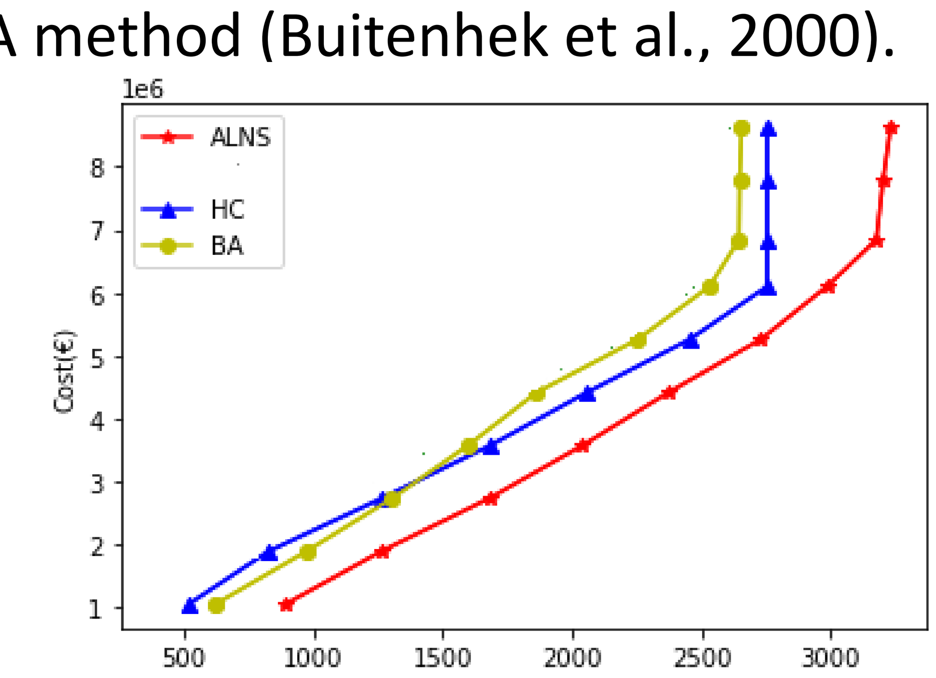
Such that: $TC \geq \lambda$

n = #insertion stations, R = #robots, W, L, λ given.

Solution: change OQN model, step 1 into closed queuing network and solve using AMVA method (Buitenhek et al., 2000).

Results: 1) ALNS is better than BA and HC (=Deppon)
2) BA outperforms HC at low TCs, at high TCs HC is better.

Future work: extend to different topologies



10-years total multi-annual cost,
$W = 6, L = 4, C_{ls} = €12.5K, \ C_R = €25K$

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