Dynamic Pickup and Delivery with Transfers

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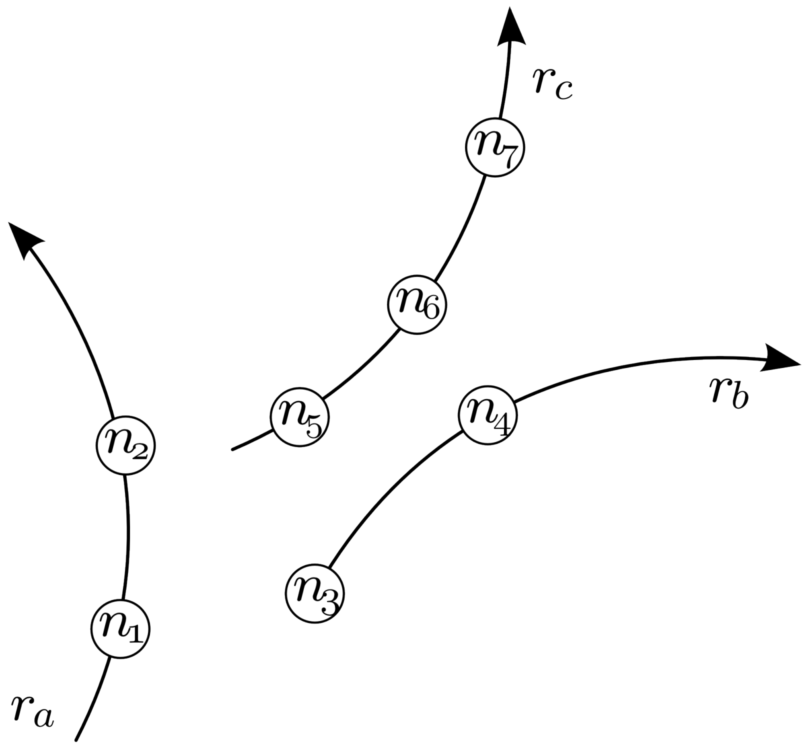
Outline

- Introduction
- Related work
  - Pickup and delivery problems
  - Shortest path problems
- Solving dynamic Pickup and Delivery with Transfers
  - Actions
  - Dynamic plan graph
  - The SP algorithm
- Experimental evaluation
- Conclusions and Future work

Motivation example

- A courier company offering pickup and delivery services
- Static plan
  - Set of requests
  - Transfers between vehicles
  - Collection of vehicles routes
- Pickup and Delivery with Transfers
  - Create static plan
- Ad-hoc requests
  - Pickup package from n_s, deliver it at n_e
- dynamic Pickup and Delivery with Transfers (dPDPT)
  - Modify static plan to satisfy new request



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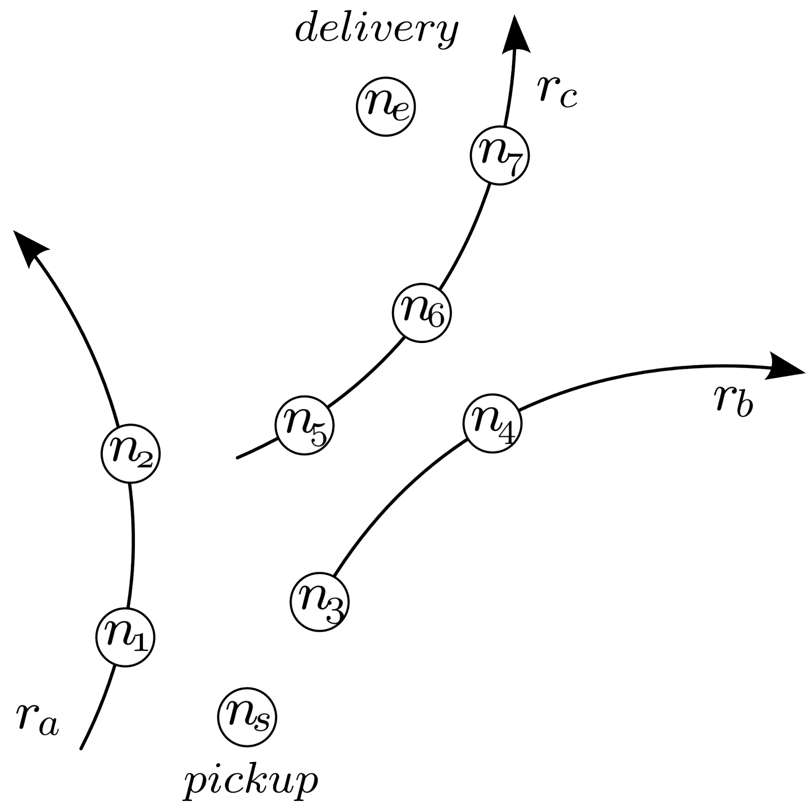

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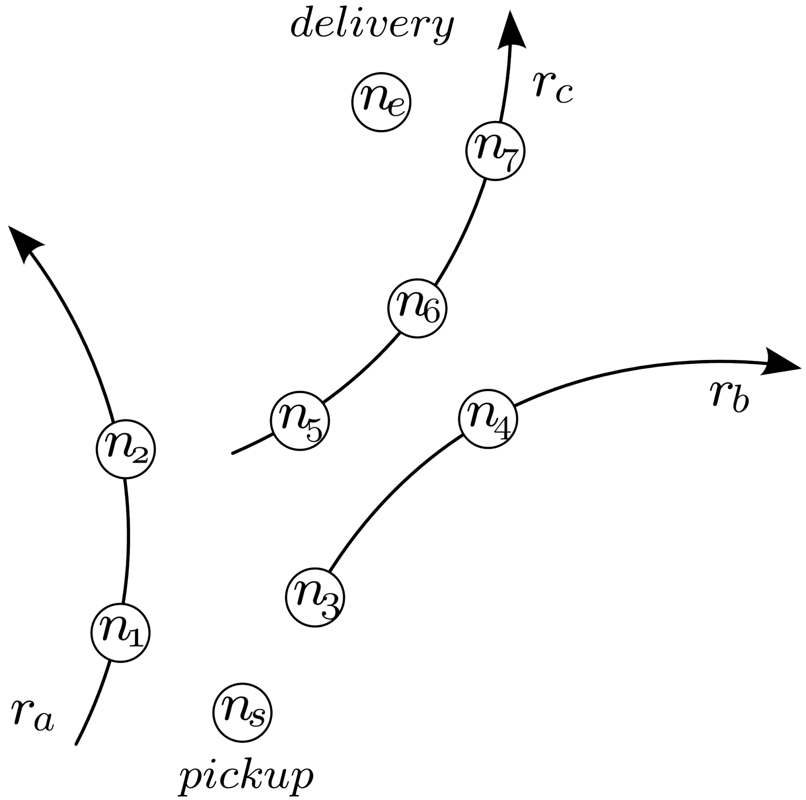

Contributions

- First work targeting dPDPT
  - Works for dynamic Pickup and Delivery can be adapted to work with transfers
- dPDPT as a graph problem
  - Works for dynamic Pickup and Delivery involve two-phase local search method
- Cost metrics
  - Company's viewpoint, extra traveling or waiting time
  - Customer's viewpoint, delivery time
- Solution
  - Dynamic two-criterion shortest path

Related work

- Pickup and delivery problems
  - Precedence and pairing constraints
  - Variations
    - Time windows
    - Capacity constraint
    - Transfers
  - Static
    - Generalization of TSP
    - Exact solutions
      - Column generation, branch-and-cut
    - Approximation
      - Local search
  - Dynamic
    - Two phases, insertion heuristic and local search

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Related work (cont'd)

- Shortest path problems
  - Classic
    - Dijkstra, Bellman-Ford
    - ALT: bidirectional A*, graph embedding
    - Materialization and labeling techniques
  - Multi-criteria SP
    - Reduction to single-criterion: user-defined preference function
    - Interaction with decision maker
    - Label-setting or correcting algorithms: a label for each path reaching a node
  - Time-dependent SP
    - Cost from n_i to n_j depends on departure time from n_i
    - Dijkstra: consider earliest possible arrival time
    - FIFO, non-overtaking property

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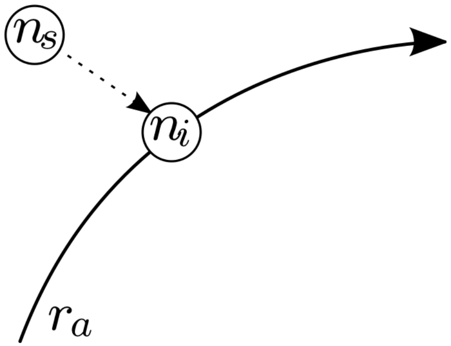
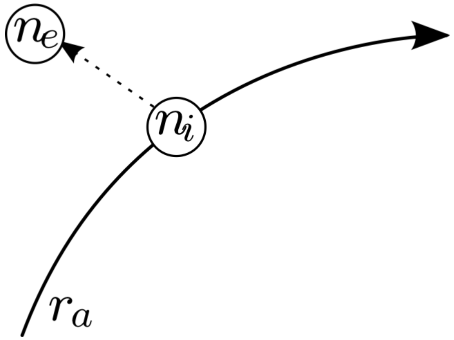
Solving dPDPT

- Modify static plan
  - 4 modifications, called actions, allowed with/without detours
    - Pickup, delivery
    - Transport
    - Transfer
- A sequence of actions, path p
  - Operational cost Op
  - Customer cost Cp
- Dynamic plan graph
  - All possible actions
- Solution to a dPDPT request
  - Path p with that primarily minimizes Op, secondarily Cp

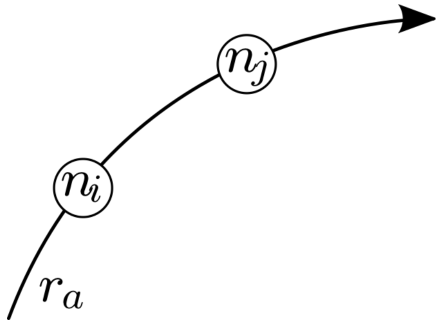
Actions



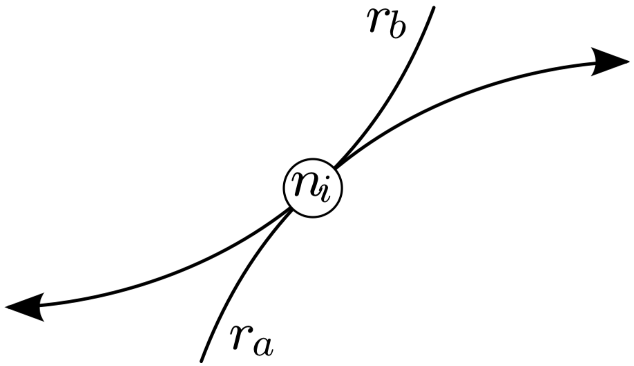
Pickup with detour



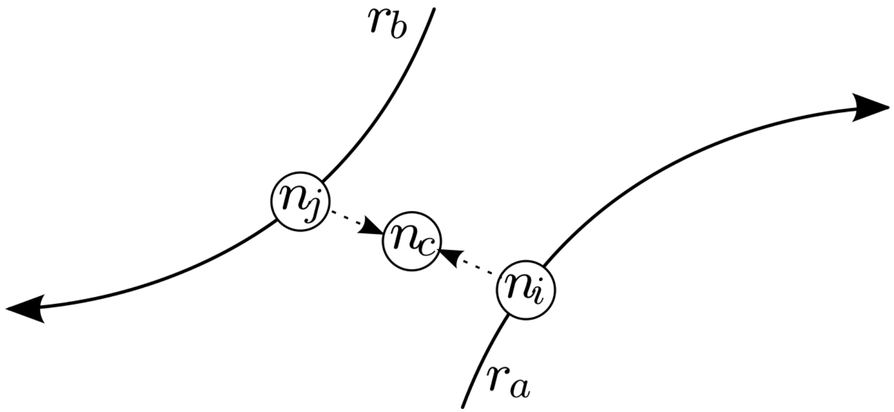
Delivery with detour



Transport

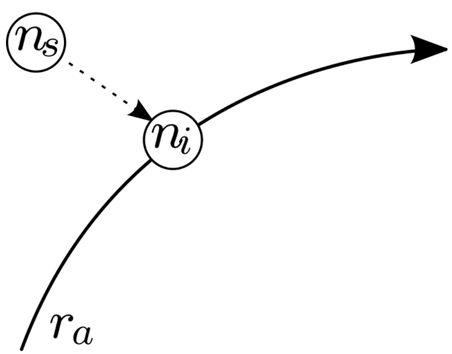


Transfer without detour

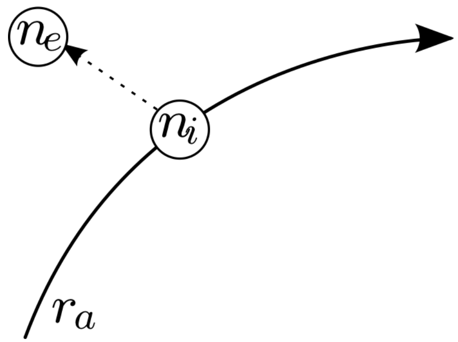


Transfer with detour

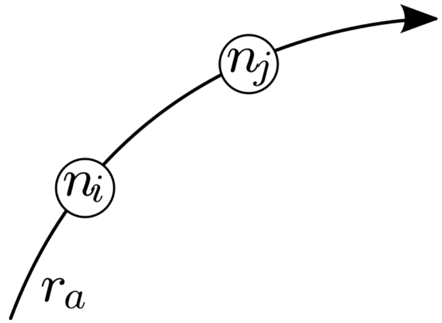
Actions



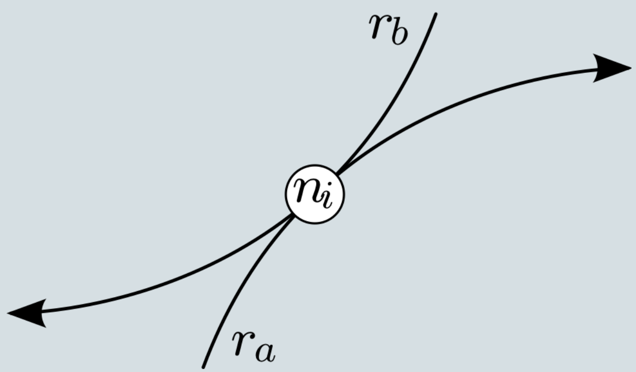
Pickup with detour



Delivery with detour



Transport

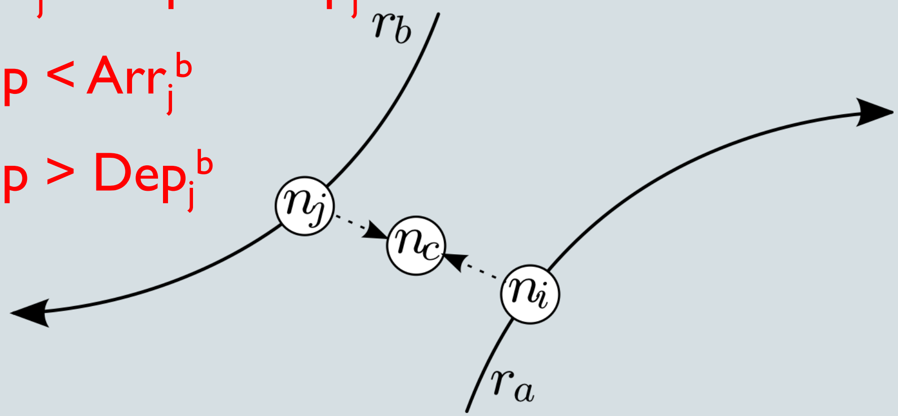


Transfer without detour

If $Arr_j^b < Cp < Dep_j^b$

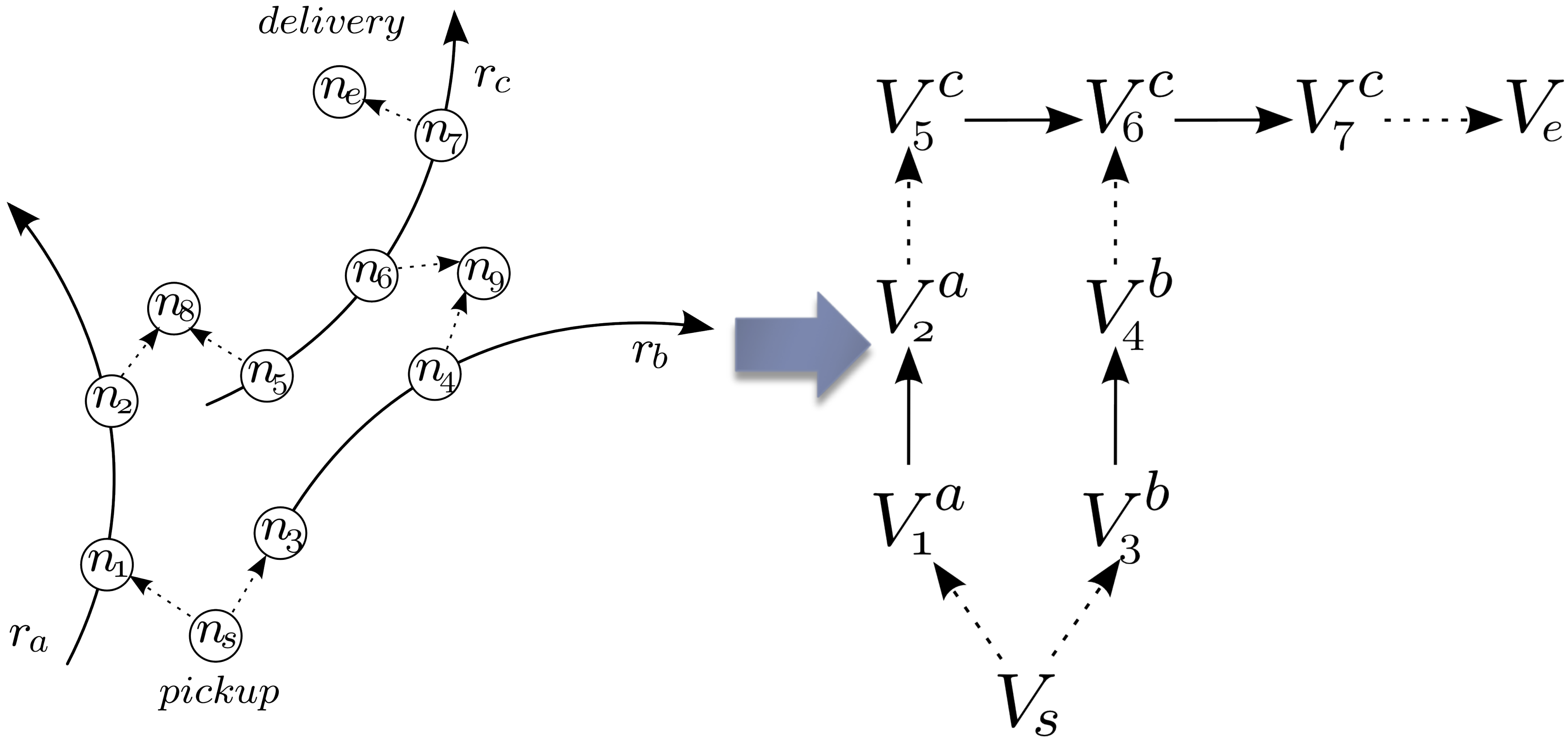
If $Cp < Arr_j^b$

If $Cp > Dep_j^b$



Transfer with detour

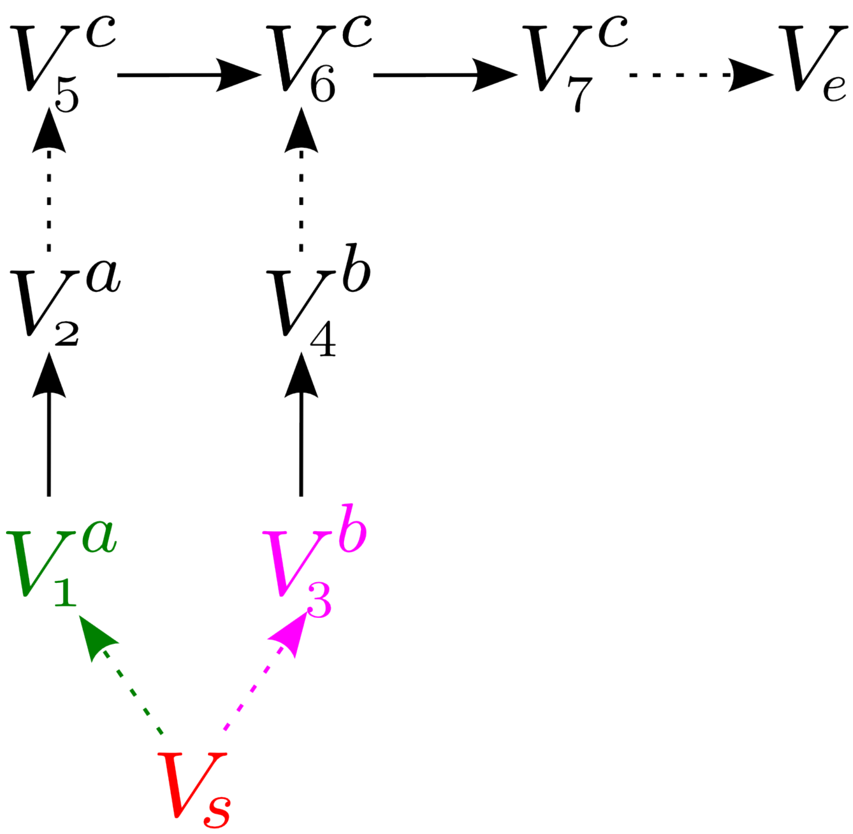
Dynamic plan graph



The SP algorithm

- Shortest path on dynamic plan graph
- BUT:
  - Dynamic plan graph violates subpath optimality
    - Answer path $(V_s,\ldots,V_i,\ldots,V_e)$ to $dPDPT(n_s,n_e)$ does not contain answer path $(V_s,\ldots,V_i)$ to $dPDPT(n_s,n_i)$
  - Cannot adopt Dijkstra or Bellman-Ford
- The SP algorithm
  - Label-setting for two-criteria, Op and Cp
    - A label $<V_i^a,p,Op,Cp>$ for each path to V_i^a
  - At each iteration select label with lowest combined cost
  - Compute candidate answer – upper bound
    - When a delivery edge is found
    - Prune search space
    - Terminate search

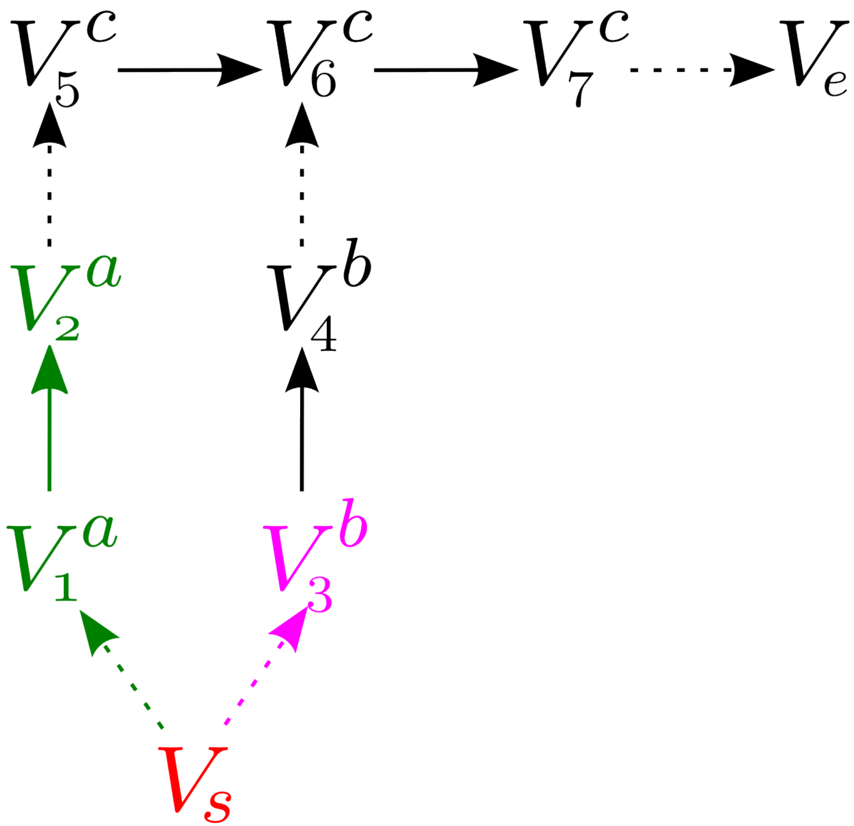
The SP algorithm (cont'd)



Detour cost T = 6

- INITIALIZATION
- CONSIDER pickup E_{s1}^a and E_{s3}^b
- $Q = \{<V_1^a, (V_s,V_1^a),6,16>, <V_3^b,(V_s,V_3^b),6,36>\}$
- P_{cand} = null

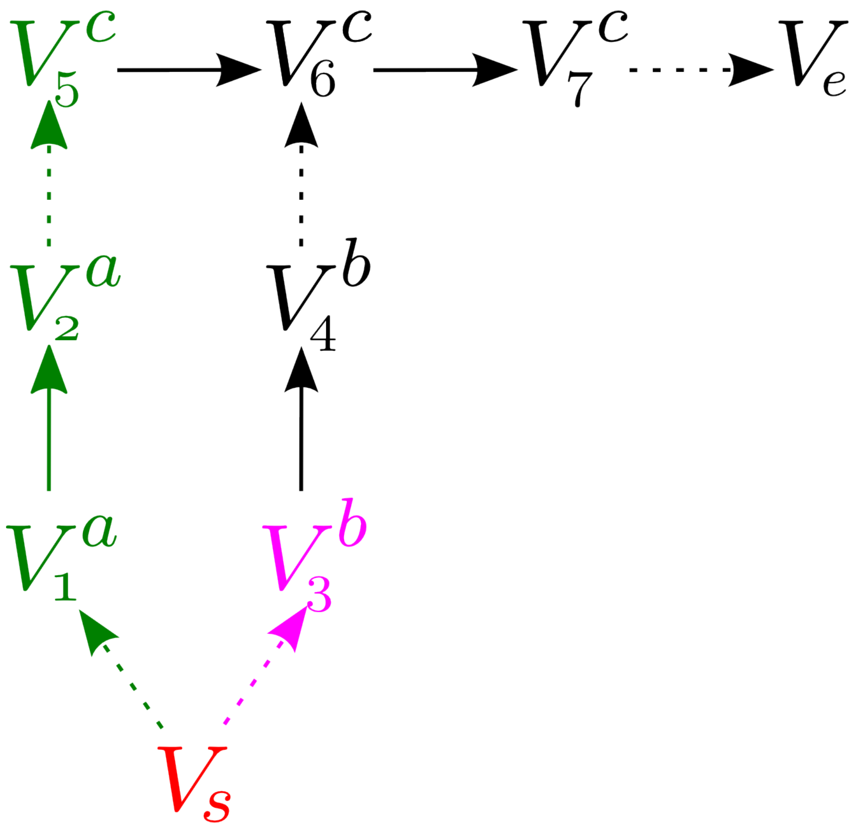
The SP algorithm (cont'd)



- POP $<V_1^a, (V_s, V_1^a), 6, 16>$
- CONSIDER transport E_{12}^a
- Q = $\{<V_2^a, (V_s, V_1^a, V_2^a), 6, 26>, <V_3^b, (V_s, V_3^b), 6, 36>\}$
- P_{cand} = null

Detour cost T = 6

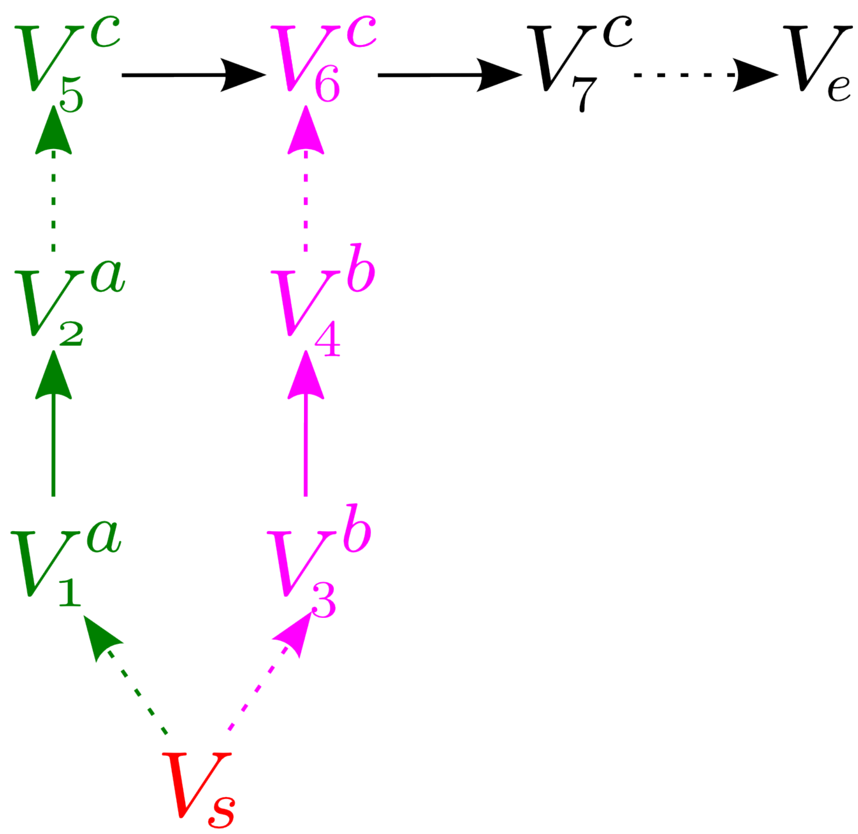
The SP algorithm (cont'd)



- POP $\langle V_2^a, (V_s, V_1^a, V_2^a), 6, 26 \rangle$
- CONSIDER transfer E_{25}^{ac}
- $Arr_5^c = 10 < 26 < Dep_5^c = 40$
- $Q = \{\langle V_3^b, (V_s, V_3^b), 6, 36 \rangle, \langle V_5^c, (V_s, V_1^a, V_2^a, V_5^c), 18, 36 \rangle\}$
- P_{cand} = null

Detour cost T = 6

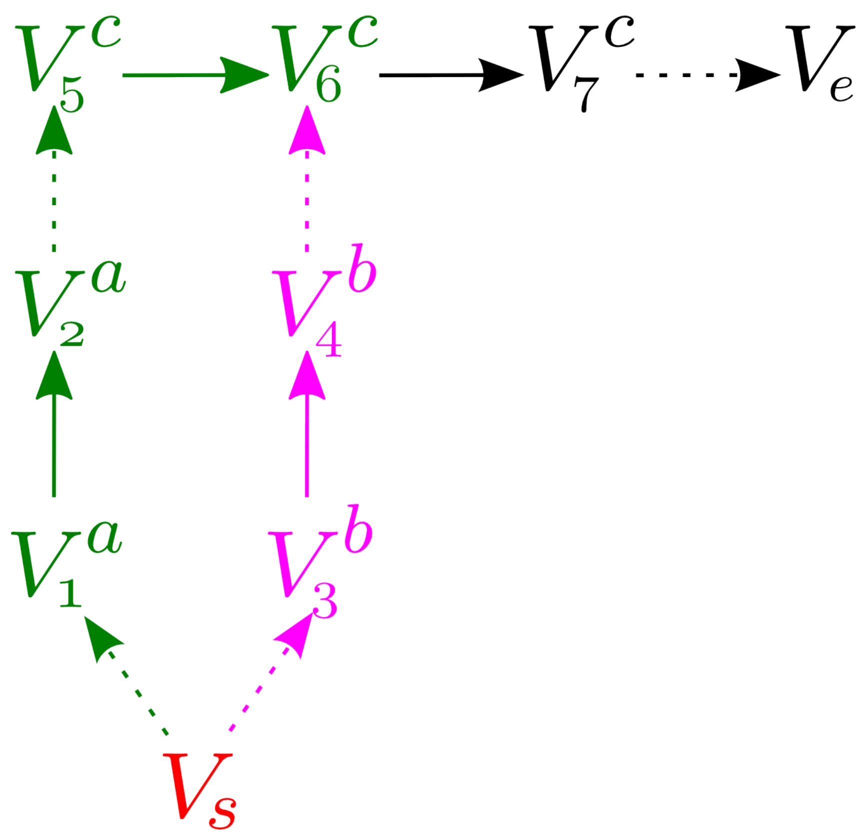
The SP algorithm (cont'd)



Detour cost T = 6

- POP $<V_3^b, (V_s,V_3^b),6,36>$ and $<V_4^b, (V_s,V_3^b,V_4^b), 6,46>$
- CONSIDER transport E_{34}^b and transfer E_{46}^{bc}
- $46 > Dep_6^c = 40$
- $Q = \{<V_5^c,(V_s,V_1^a,V_2^a,V_5^c), 18,36>, <V_6^c, (V_s,V_3^b,V_4^b,V_6^c),24,52>\}$
- P_{cand} = null

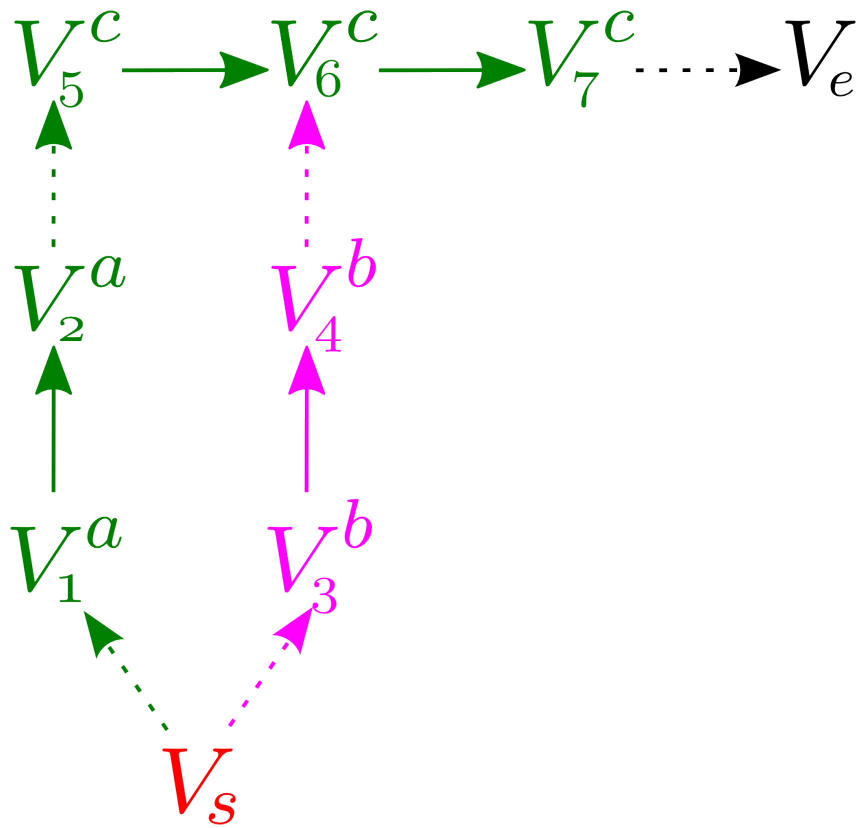
The SP algorithm (cont'd)



Detour cost T = 6

- POP $<V_5^c,(V_s,V_1^a,V_2^a,V_5^c), 18,36>$
- CONSIDER transport E_{56}^c
- Q = $\{<V_6^c, (V_s,V_1^a,V_2^a,V_5^c,V_6^c),18, 46>, <V_6^c,(V_s,V_3^b,V_4^b,V_6^c), 24,52>\}$
- P_{cand} = null

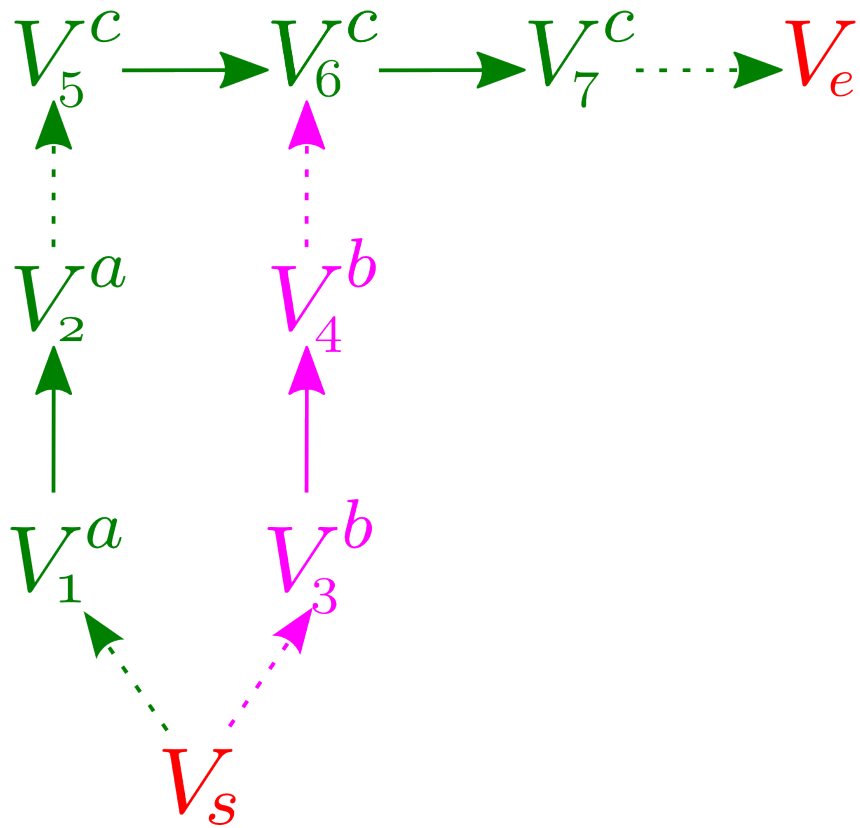
The SP algorithm (cont'd)



- POP $<V_6^c, (V_s, V_1^a, V_2^a, V_5^c, V_6^c), 18, 46>$
- CONSIDER transport E_{67}^c
- $Q = \{<V_7^c, (V_s, V_1^a, V_2^a, V_5^c, V_6^c, V_7^c), 18, 56>, <V_6^c, (V_s, V_3^b, V_4^b, V_6^c), 24, 52>\}$
- P_{cand} = null

Detour cost T = 6

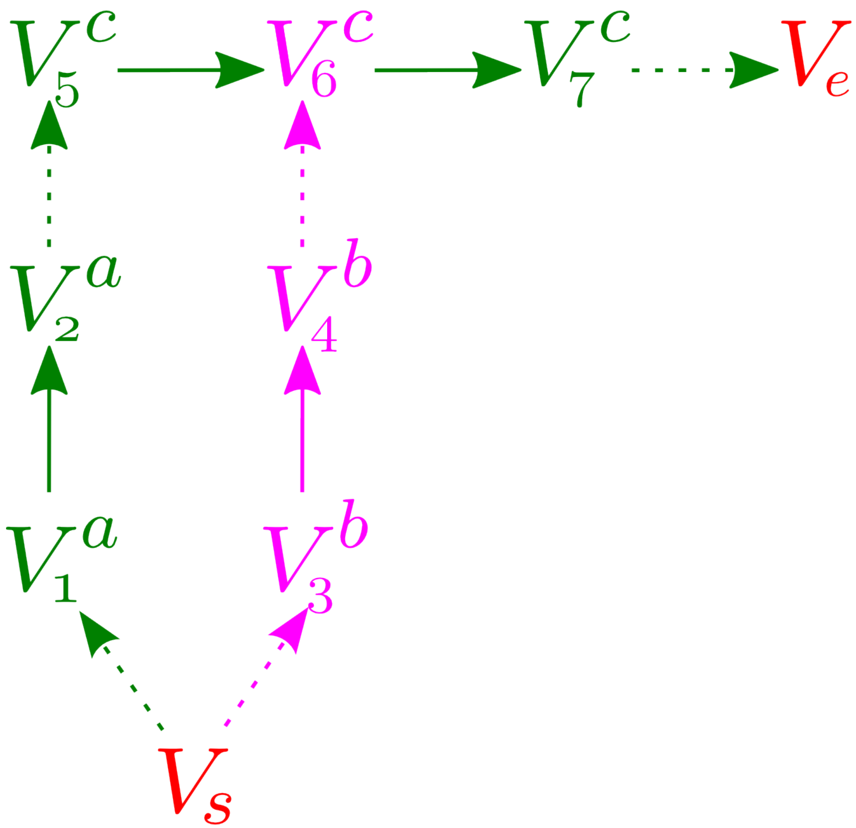
The SP algorithm (cont'd)



Detour cost T = 6

- POP $<V_7^c, (V_s, V_1^a, V_2^a, V_5^c, V_6^c, V_7^c), 18{,}56>$
- CONSIDER delivery E_{7e}^c
- FOUND p_{cand}
- Q = $\{<V_6^c, (V_s, V_3^b, V_4^b, V_6^c), 24{,}52>\}$
- $p_{cand} = (V_s, V_1^a, V_2^a, V_5^c, V_6^c, V_7^c, V_e)$
- $Op_{cand} = 24$
- $Cp_{cand} = 59$

The SP algorithm (cont'd)



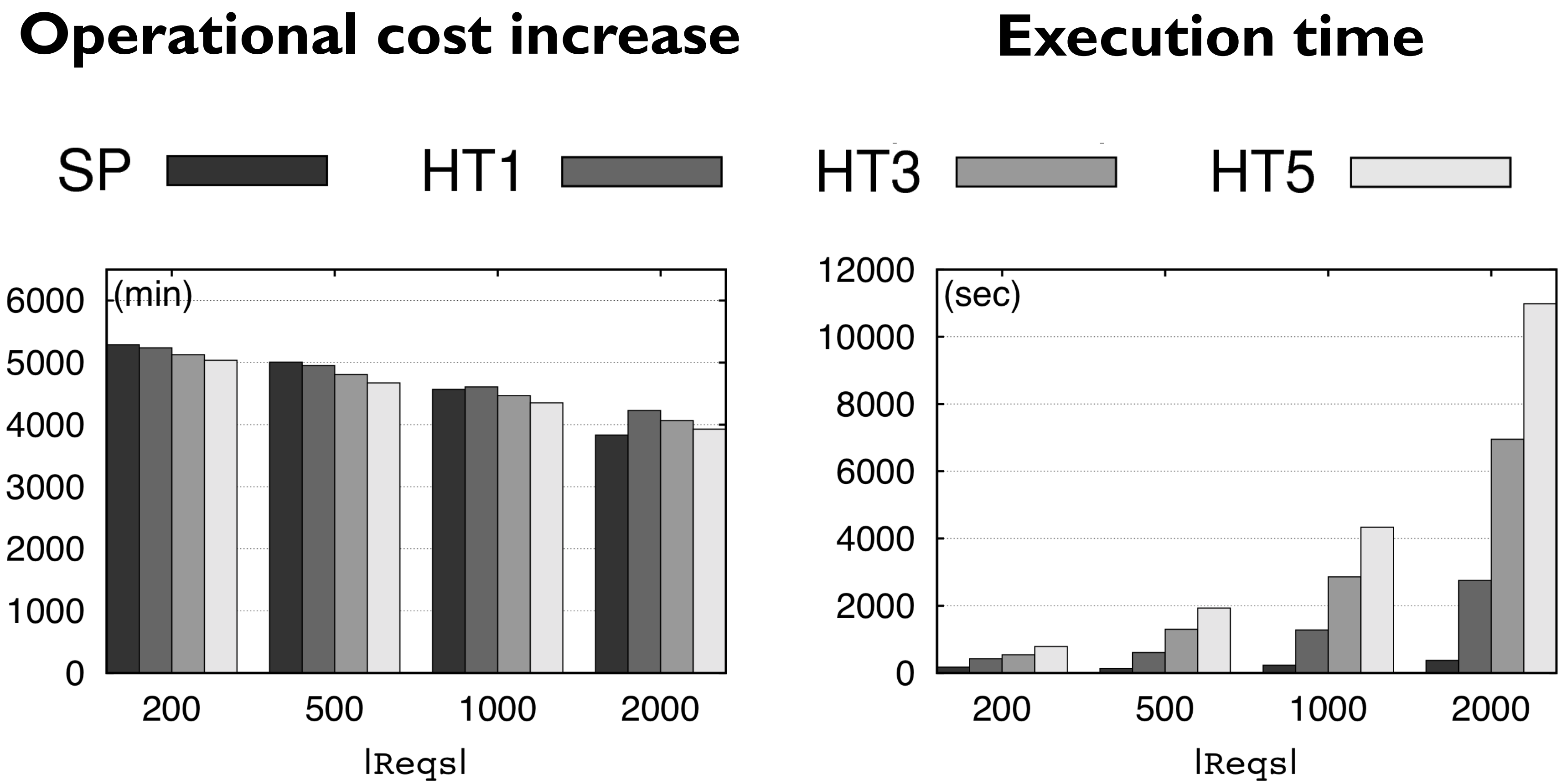
- POP $<V_6^c,(V_s,V_3^b,V_4^b,V_6^c), 24,52>$
- $Op_{cand} = 24$
- STOP

Detour cost T = 6

Experimental analysis

- Rival: two-phase method, HT
  - Cheapest insertion for pickup and delivery location, for every new request
  - After k requests perform tabu search
- Datasets
  - Road networks, OL with 6105 locations, ATH with 22601 locations
  - Static plan with HT method
    - Vary |Reqs| = 200, 500, **1000**, 2000
    - Vary |R| = 100, 250, **500**, 750, 1000
  - Stored on disk
- Experiments
  - 500 dPDPT requests
  - HT1, HT3, HT5
- Measure
  - Total operational cost increase
  - Total execution time
  - 10% cache

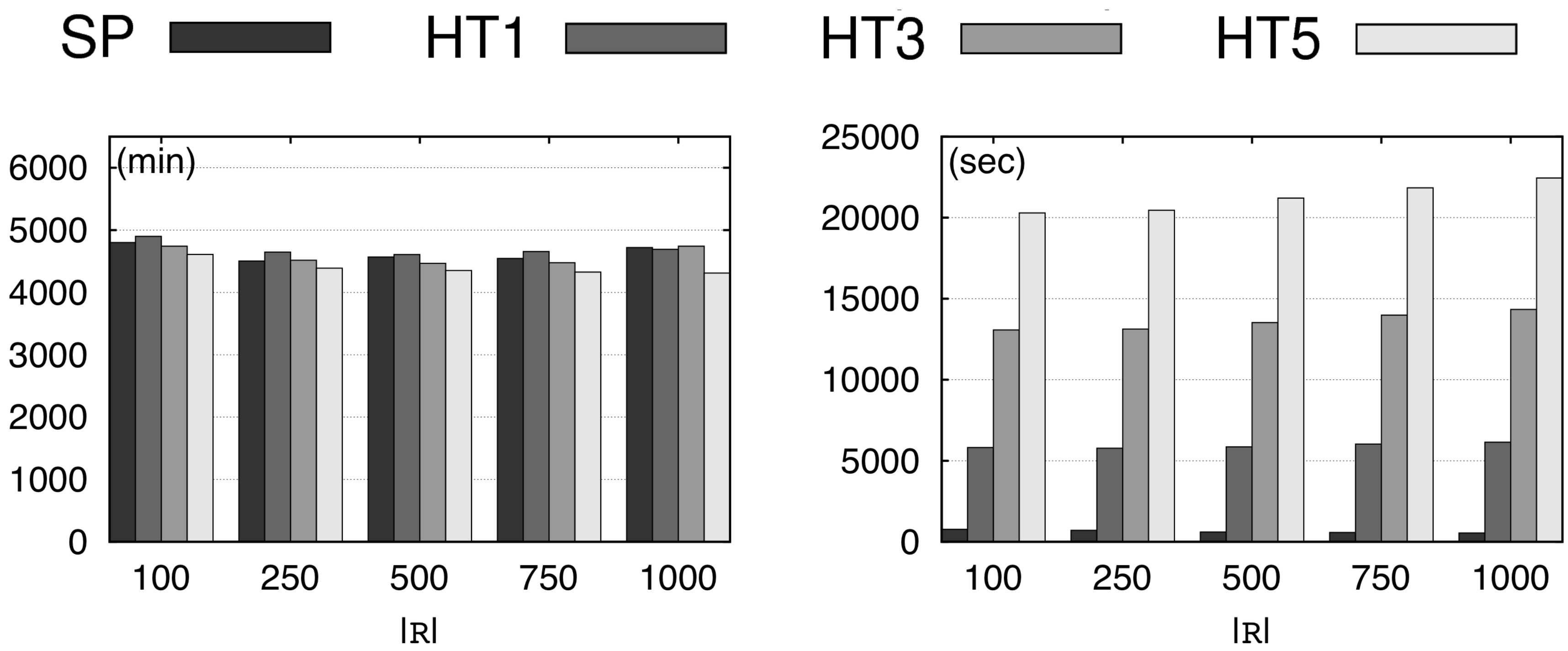
Varying |Reqs|



OL road network

Varying |R|

Operational cost increase **Execution time**



OL road network

To sum up

- Conclusions
  - First work on dPDPT
  - Formulation as graph problem
  - Solution as dynamic two-criterion shortest path
  - Faster than a two-phase local search-based method, solutions of marginally lower quality
- Future work
  - Subpath optimality
  - Exploit reachability information within routes
  - Additional constraints, e.g., vehicle capacity

Questions ?


operational cost
dynamic
transfer
two-criterion
detour
pickup
customer cost
delivery
shortest path