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PRE- AND END-HAULAGE OPERATIONS IN A MULTI-DEPOT AND MULTI-RESOURCE SYNCHROMODAL NETWORK

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CONTENTS

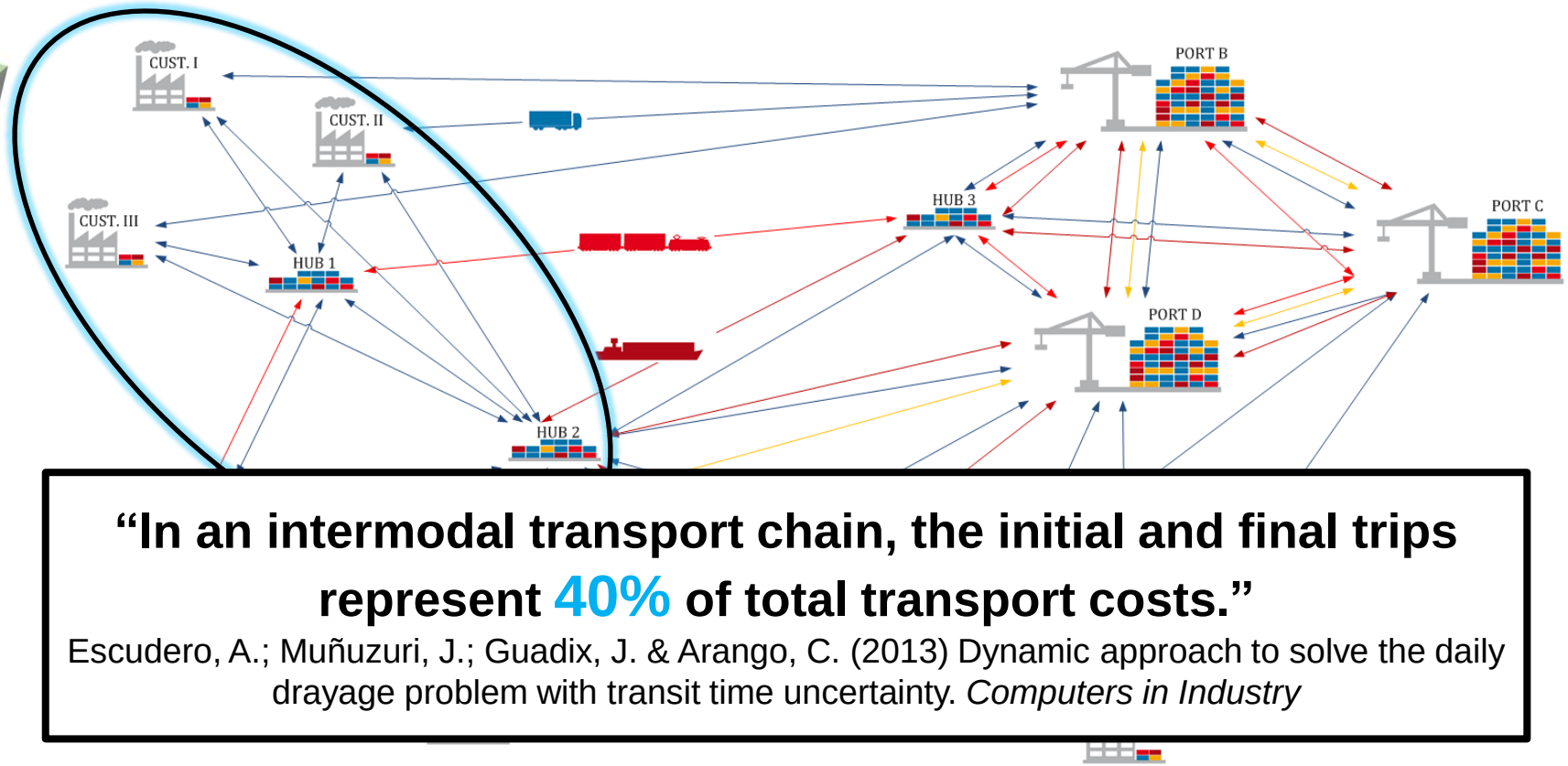

CTT
INTERMODAAL TRANSPORT

TRANSPORTATION OF CONTAINERS FROM THE HINTERLAND TO/FROM THE DEEP-SEA PORT

**Source of artwork: Combi Terminal Twente B.V. www.ctt-twente.nl*

FREIGHT IN A SYNCHROMODAL NETWORK

DYNAMIC, MODE-FREE, NETWORK-WISE DECISION MAKING



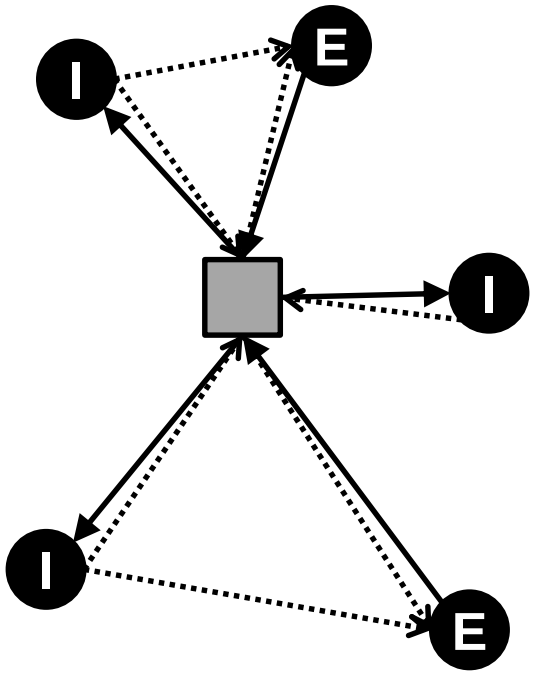
"In an intermodal transport chain, the initial and final trips represent 40% of total transport costs."

Escudero, A.; Muñuzuri, J.; Guadix, J. & Arango, C. (2013) Dynamic approach to solve the daily drayage problem with transit time uncertainty. *Computers in Industry*

**Source of artwork: Europe Container Terminals "The future of freight transport". www.ect.nl*

PRE- AND END-HAULAGE OPERATIONS

THE BASIC EXPORT/IMPORT (SHIPPER/CONSIGNEE, DRAYAGE) OPERATIONS



Intermodal terminal

Customer has/needs a full container

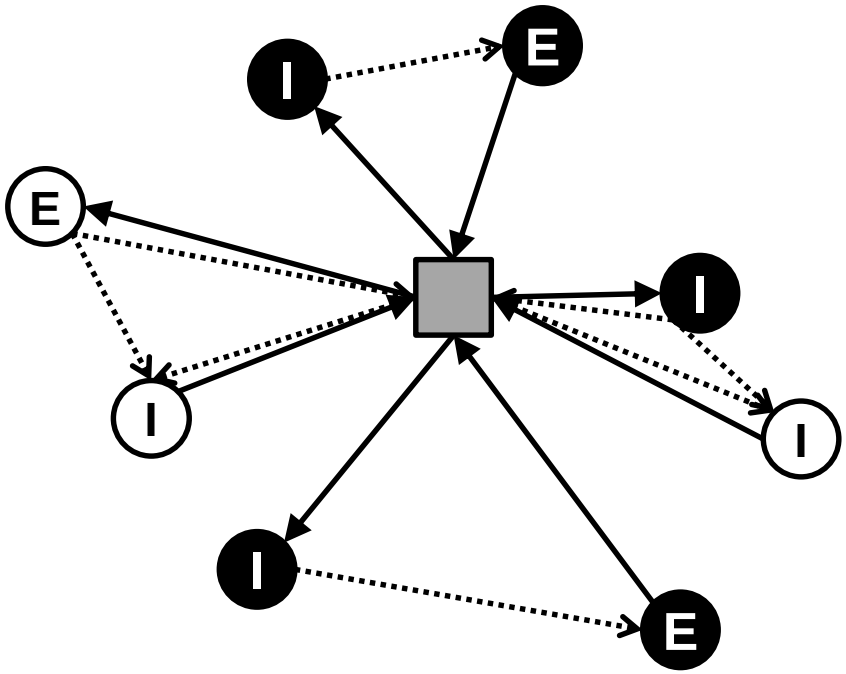
Truck with a loaded container

Truck without a container

I: Import , E: Export

PRE- AND END-HAULAGE OPERATIONS

ADDING EMPTY CONTAINERS



Intermodal terminal

Customer has/needs a full container

Customer has/needs an empty container

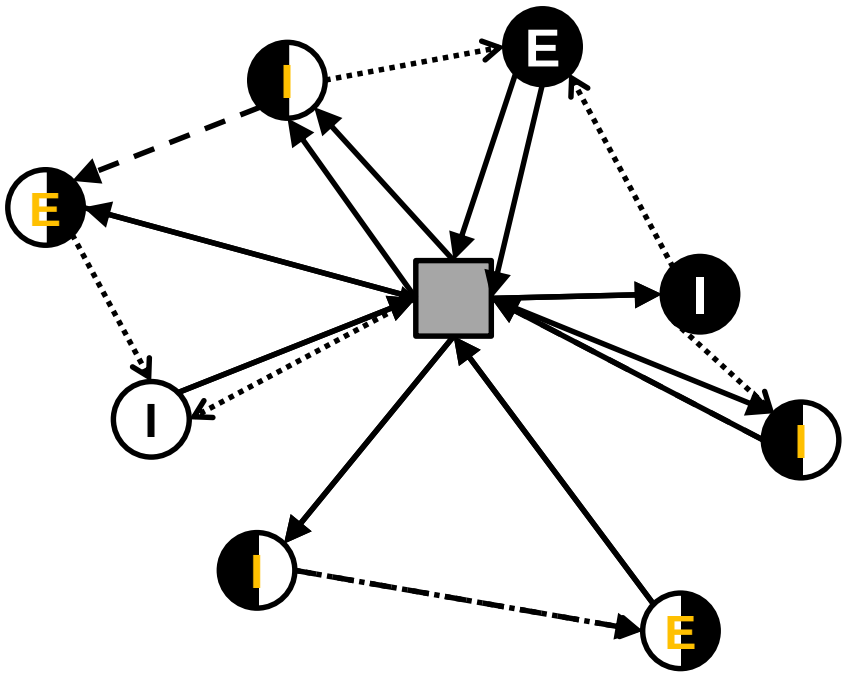
Truck with a loaded container

Truck without a container

I: Import , E: Export

PRE- AND END-HAULAGE OPERATIONS

ADDING COMPLETE JOBS (RESOURCE DIFFERENTIATION)



Intermodal terminal

Customer has/needs a full container

Customer has/needs an empty container

Customer complete end-haulage

Customer complete pre-haulage

Truck with a loaded container

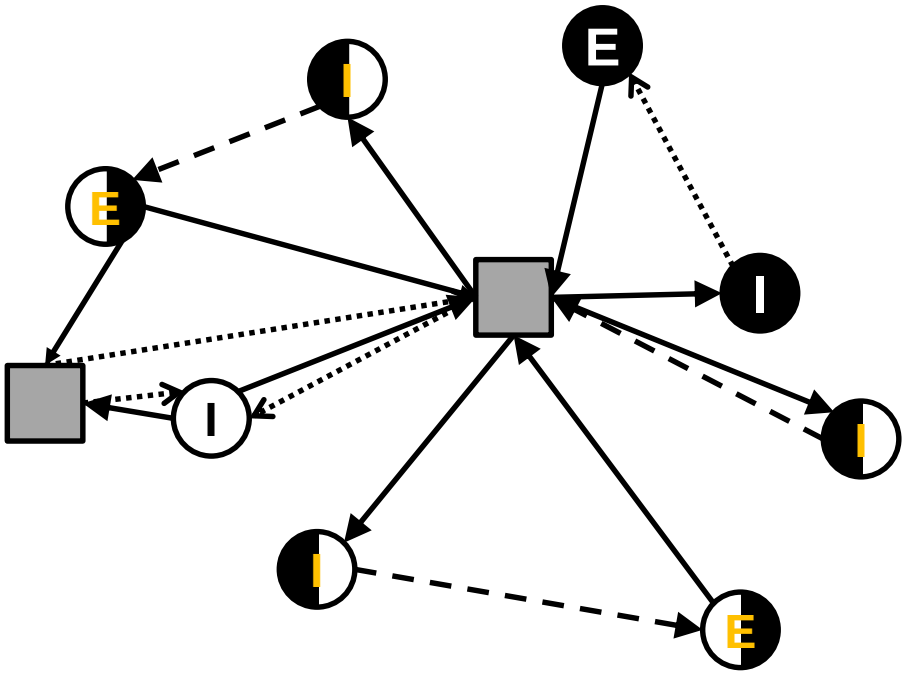
Truck without a container

Truck with empty container

I: Import , E: Export

PRE- AND END-HAULAGE OPERATIONS

ADDING MULTIPLE INTERMODAL TERMINALS



Intermodal terminal

Customer has/needs a full container

Customer has/needs an empty container

Customer complete end-haulage

Customer complete pre-haulage

Truck with a loaded container

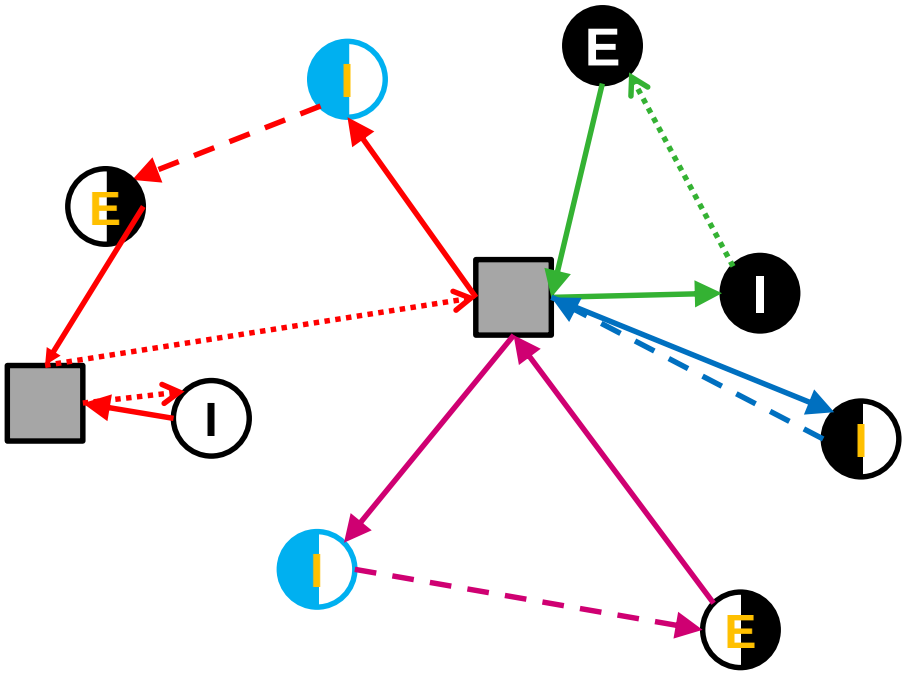
Truck without a container

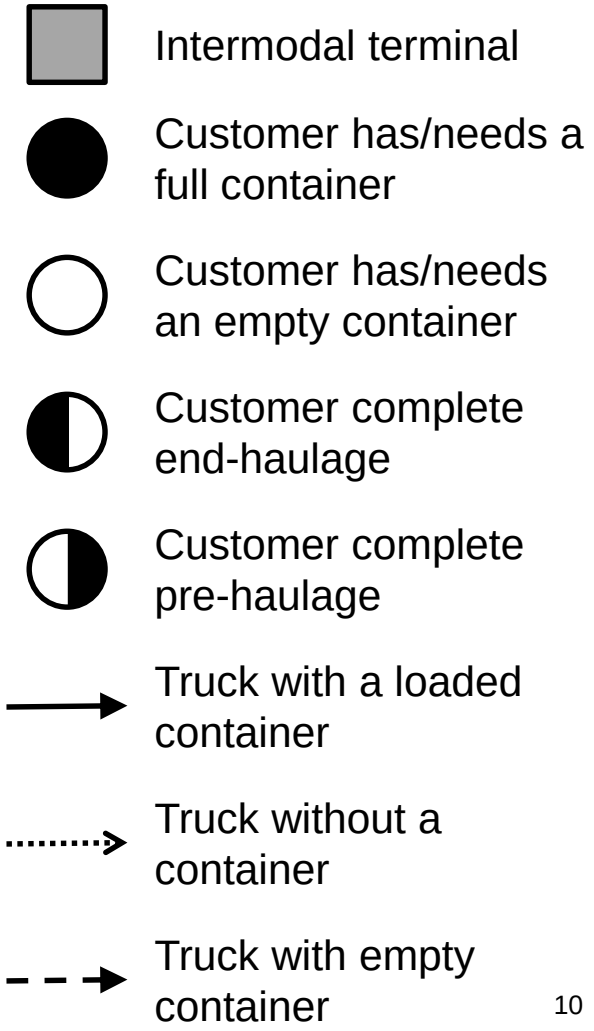
Truck with empty container

I: Import , E: Export

PRE- AND END-HAULAGE OPERATIONS

DECOUPLING (I.E., POSSIBLE TO SPLIT COMPLETE JOBS IN TWO)

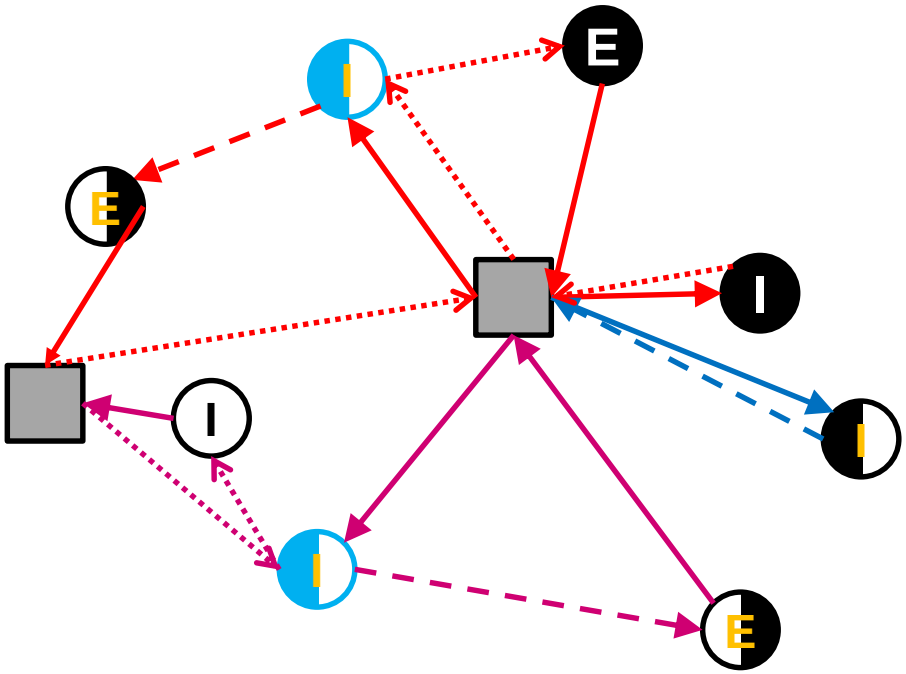


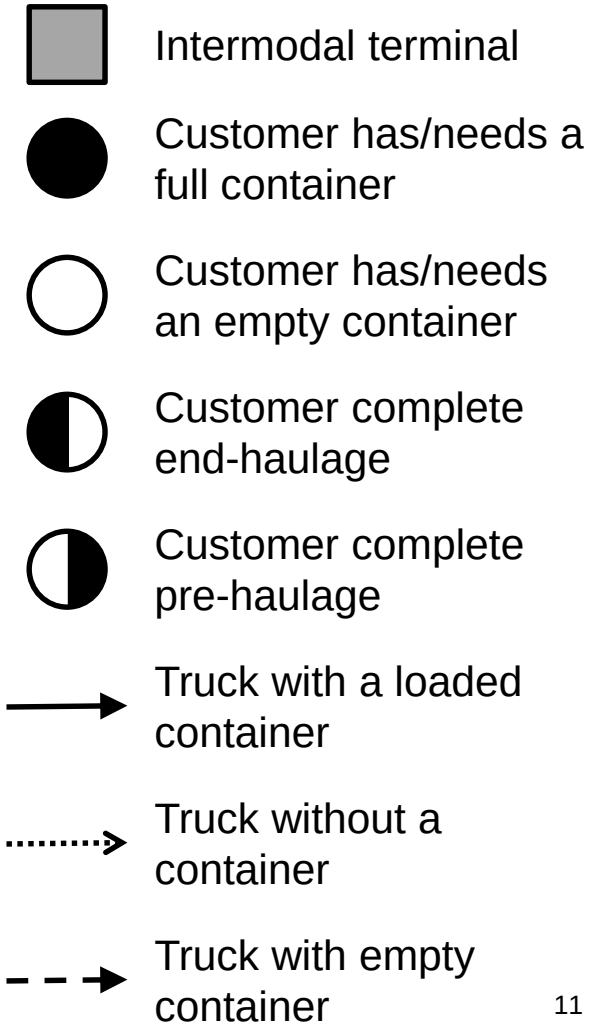


I: Import , E: Export

PRE- AND END-HAULAGE OPERATIONS

DECOUPLING (I.E., POSSIBLE TO SPLIT COMPLETE JOBS IN TWO)

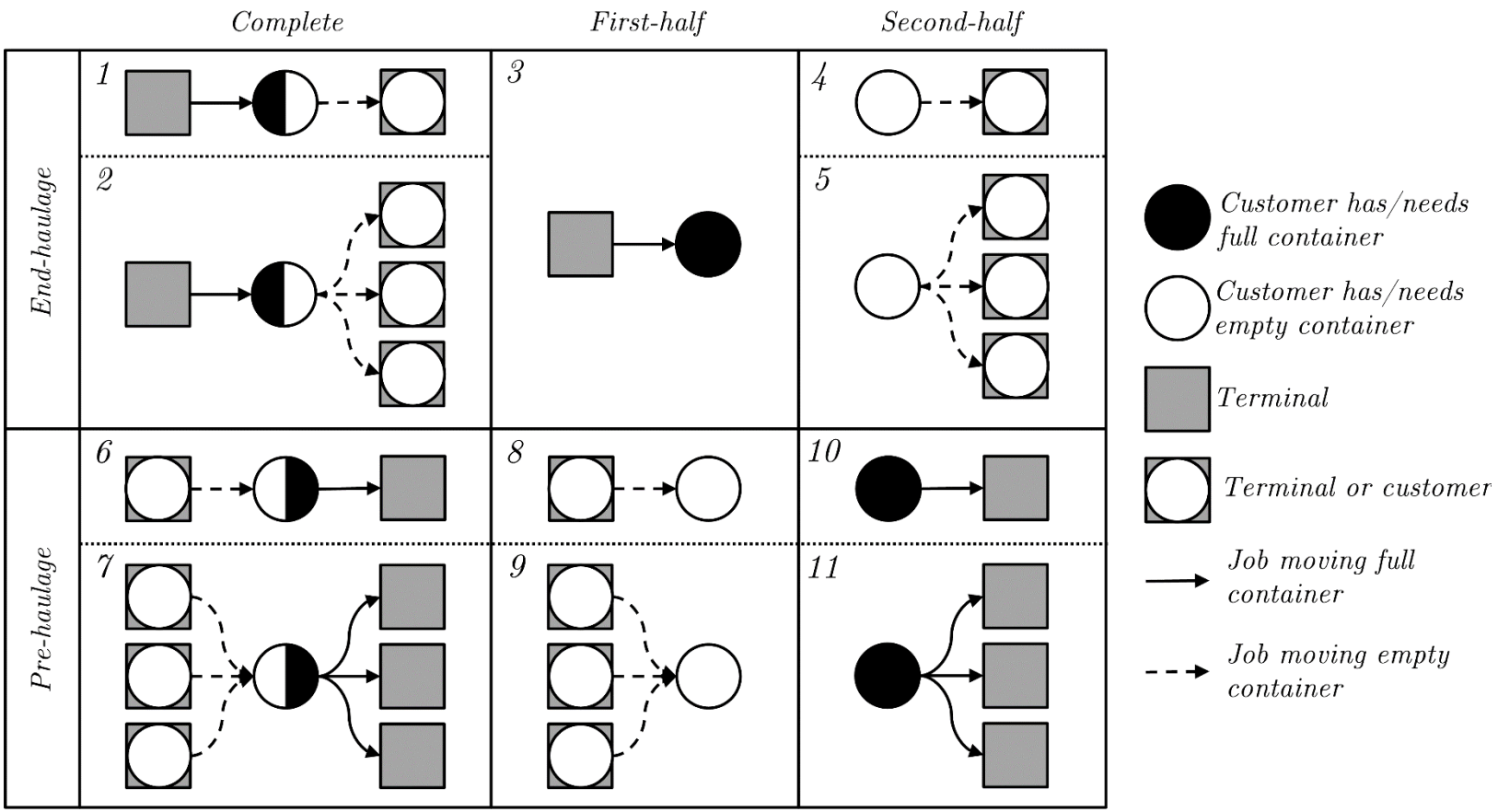




I: Import , E: Export

PRE- AND END-HAULAGE SYNCHROMODAL OPERATIONS

CATEGORIZATION OF JOBS (CUSTOMERS)



PLANNING PRE- AND END-HAULAGE OPERATIONS

PROPOSED METHODS IN THE LITERATURE

1. Wang, X. & Regan, A. C. (**2002**) Local truckload pickup and delivery with hard time window constraints *Transportation Research Part B*
2. Jula, H.; Dessouky, M.; Ioannou, P. & Chassiakos, A. (**2005**) Container movement by trucks in metropolitan

What works well?

1. ***Model enhancements*: time-window pre-processing, terminal assignment mechanisms, etc.**
2. ***Local-search operators*: merging end- and pre-haulage jobs, assigning terminals, etc.**

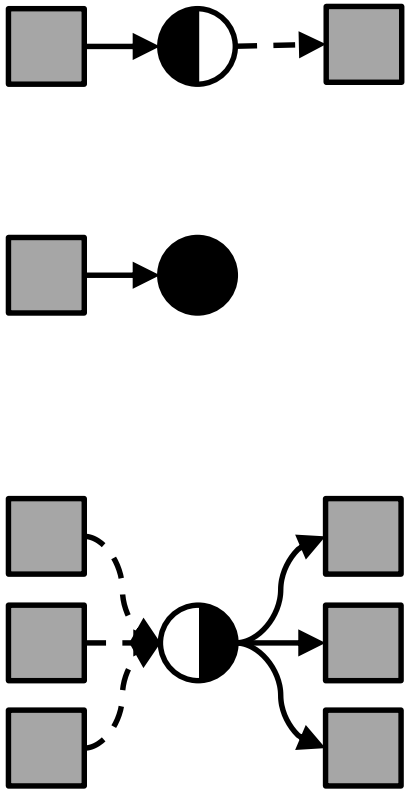
OR Spectrum

8. Zhang, G.; Smilowitz, K. & Erera, A. (**2011**) Dynamic planning for urban drayage operations *Transportation Research Part E*
9. Braekers, K.; Caris, A. & Janssens, G. (**2013**) Integrated planning of loaded and empty container movements *OR Spectrum*
10. Escudero, A.; Muñuzuri, J.; Guadix, J. & Arango, C. (**2013**) Dynamic approach to solve the daily drayage problem with transit time uncertainty. *Computers in Industry*
11. Nossack, J. & Pesch, E. (**2013**) A truck scheduling problem arising in intermodal container transportation *European Journal of Operational Research*

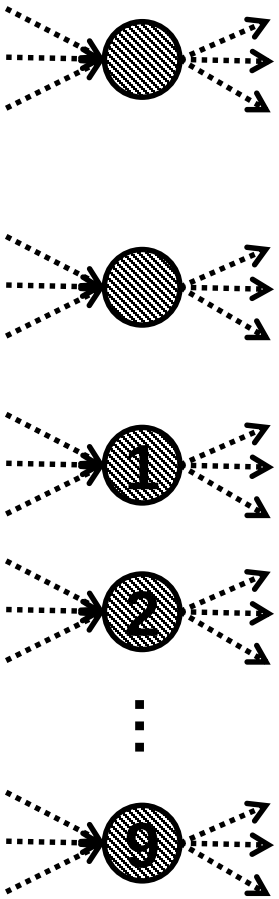
PLANNING PRE- AND END-HAULAGE OPERATIONS

MODELING JOBS USING MIXED-INTEGER LINEAR PROGRAMMING (MILP)

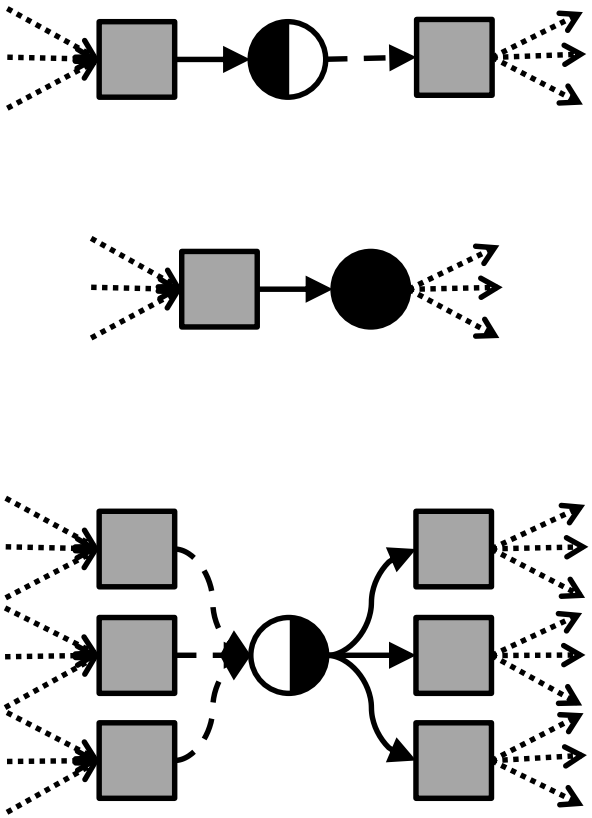
Example job



Jobs as ***nodes***



Jobs as ***arcs***



PROPOSED SOLUTION: FTPDPTW MODEL

FULL TRUCKLOAD PICKUP AND DELIVERY PROBLEM WITH TIME-WINDOWS (FTPDPTW)

$$\min z(x) = \underbrace{\sum_{k \in K} \left(C_k^F \cdot \sum_{j \in \delta'^+(B_k)} x_{B_k,j,k} \right) + \sum_{k \in K} \sum_{(i,j) \in A'} C_{i,j,k}^V \cdot x_{i,j,k}}_{\text{Trucking costs}} + \underbrace{\sum_{k \in K} \sum_{i \in V^C} \sum_{j \in \delta^+(i) \cup V^D} C_{i,j}^A \cdot x_{i,j,k}}_{\text{Long-haul mode assignment costs}} \quad (1a)$$

$$E_i \leq w_i \leq L_i, \ \forall \, i \in V \quad (1h)$$

$$\sum_{k \in K} \left(x_{i,j,k} \cdot \left(w_i + S_i + T_{i,j}^T - w_j \right) \right) \leq 0, \ \forall \, i,j \in V \quad (1i)$$

$$\sum_{k \in K} \left(x_{B_k,j,k} \cdot T_{B_k,j}^T \right) \leq w_j, \ \forall \, j \in V \quad (1j)$$

$$x_{i,F_k,k} \cdot \left(w_i + S_i + T_{i,F_k}^T - T^M \right) \leq 0, \ \forall \, i \in \delta'^-(F_k), k \in K \quad (1k)$$

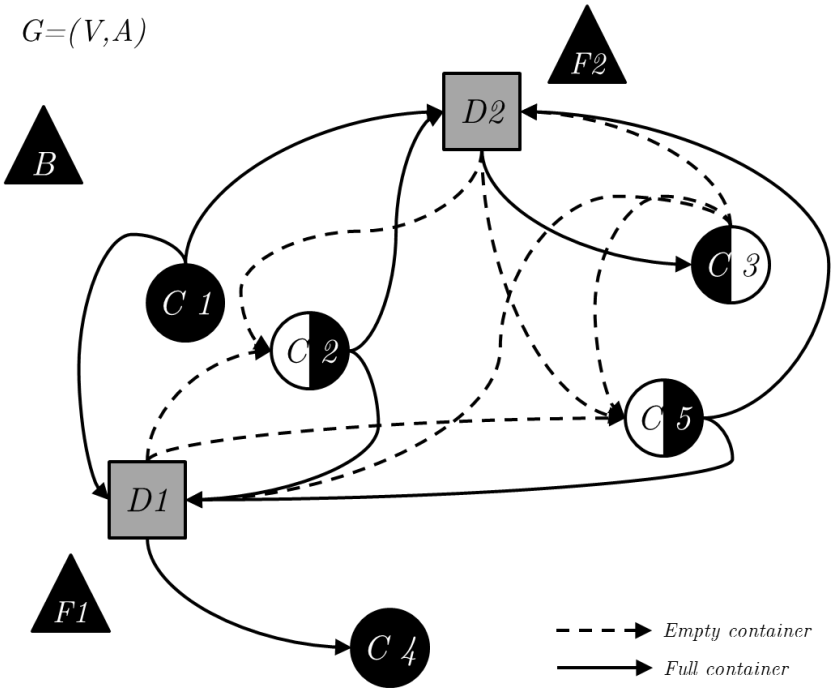
New elements in the FTPDPTW model:

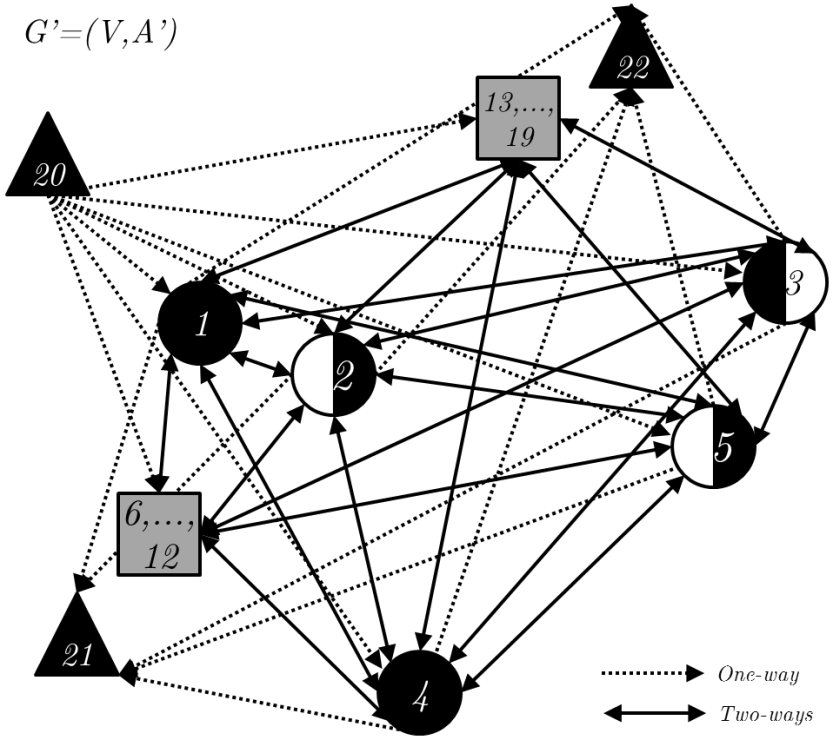
1. ***Additional term in the objective*:** terminal (long-haul mode) assignment cost
2. ***Two type of arc-constraints*:** job assignment and flow-conservation
3. ***Decoupling constraints*:** separation of job-arcs and their time-windows

$$\sum_{j \in \delta'^+(i)} x_{i,j,k} - \sum_{j \in \delta'^-(i)} x_{j,i,k} = 0, \ \forall \, i \in V^C \cup V^D, k \in K \quad (1g)$$

PROPOSED SOLUTION: FTPDPTW MODEL

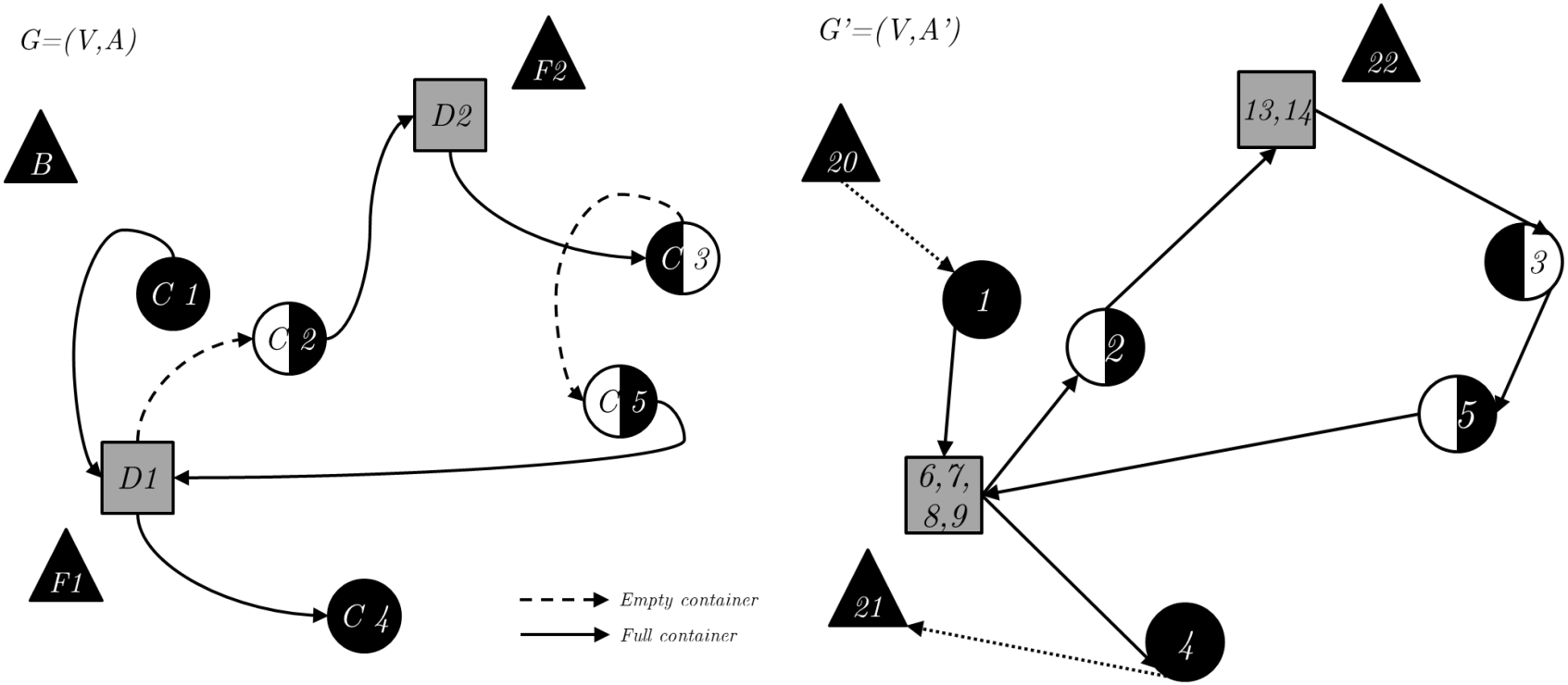
SMALL EXAMPLE





PROPOSED SOLUTION: FTPDPTW MODEL

SMALL EXAMPLE



PROPOSED SOLUTION: MILP ENHANCEMENTS

SOME VALID INEQUALITIES EXAMPLES

- ***Arcs between all terminals*****:** due to the job configurations, there is a maximum number of arcs connecting terminals that can be traveled.

$$\sum_{k \in K} \sum_{i \in V^D} \sum_{j \in V^D} x_{i,j,k} \leq M^{DE}$$

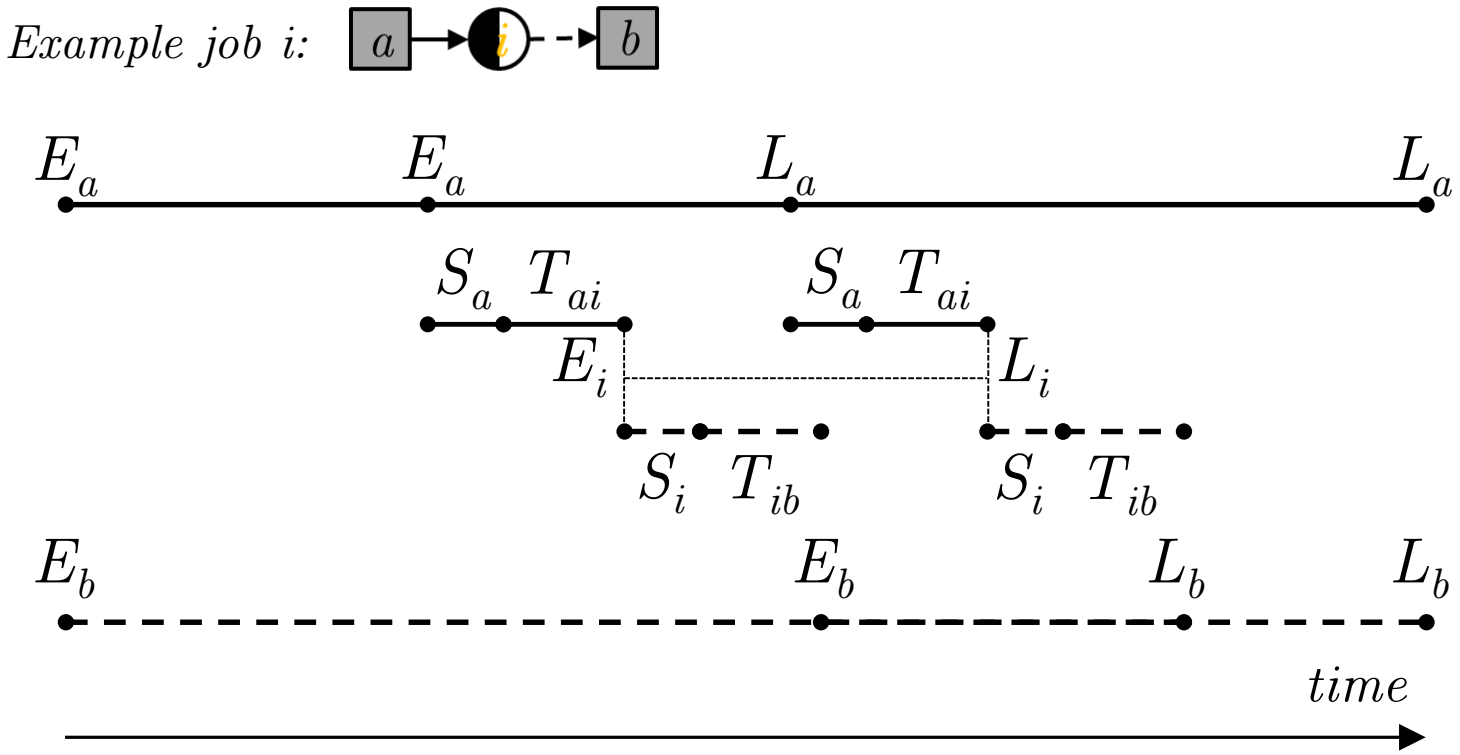
- ***Arcs between replicated nodes of a single terminal*****:** due to job configurations and possible terminals, there is a maximum number of arcs between replicated nodes.

$$\sum_{k \in K} \sum_{i \in V^D \cap \mathcal{U}_d} \sum_{j \in V^D \cap \mathcal{U}_d} x_{i,j,k} \leq M_d^{DI}, \ \forall \, d \in \mathcal{D}$$

PROPOSED SOLUTION: MILP ENHANCEMENTS

TIME-WINDOW PRE-PROCESSING EXAMPLE

- ***Shorter time-windows at depot nodes*: due to customer time-windows and replicated depot nodes, time-windows can be tighten.**



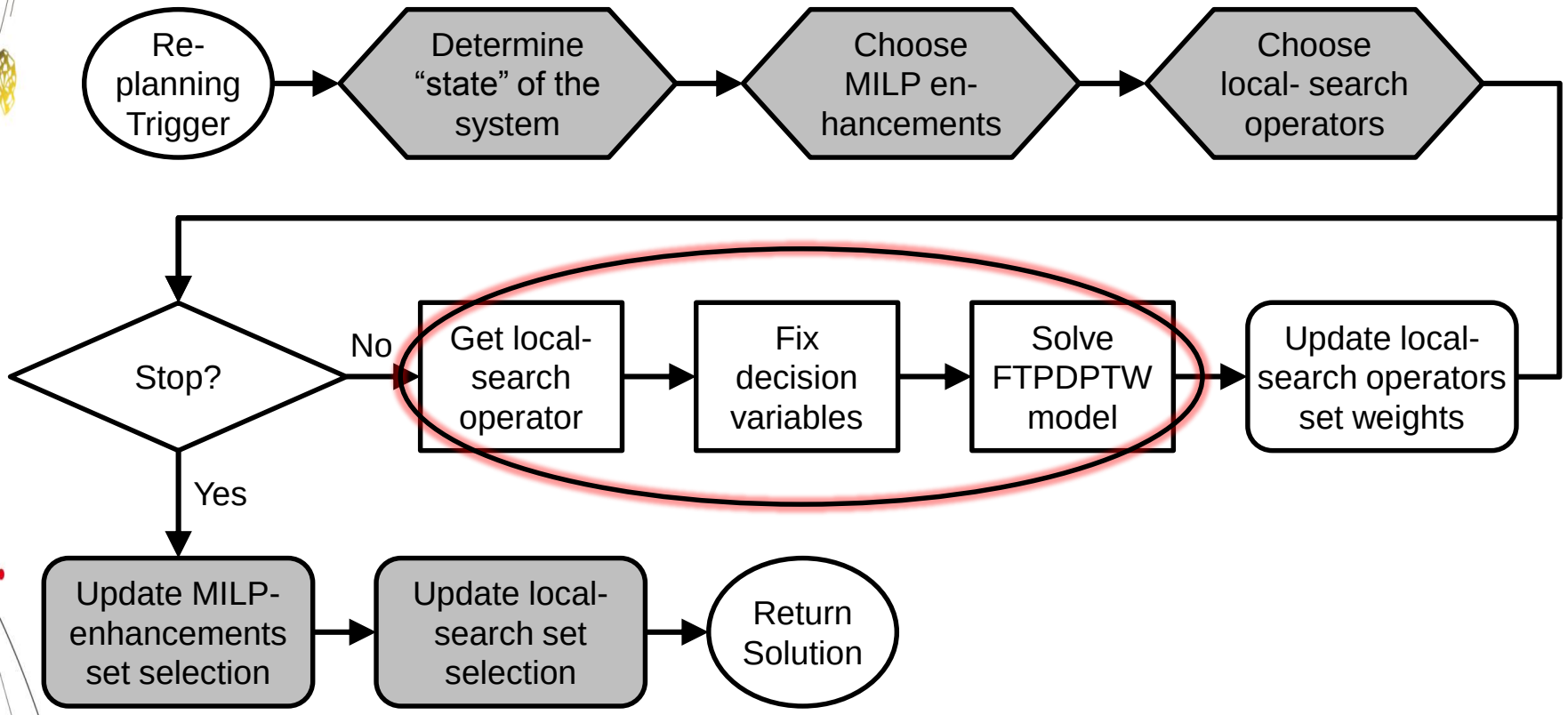
PROPOSED SOLUTION: LOCAL-SEARCH OPERATORS

SOME FIXED-VARIABLE EXAMPLES

- ***Set of trucks*:** lower/upper bound in the number of trucks used, indicator of individual trucks to use, etc.
- ***Job to trucks***: lower/upper bound on the number of jobs per truck, individual jobs done by a truck, etc.
- ***Fix customer-terminal jobs*:** following a “range” criteria such as distance, time-window overlap, costs, etc.
- ***Fix customer-customer jobs*:** following a “range” criteria such as distance, time-window overlap, costs, etc., or a “job-configuration” criteria such as number of destinations, number of terminal origins, etc.

PROPOSED SOLUTION: ALNS-BASED HEURISTIC

SOLVING THE FTPDPTW MODEL, DYNAMICALLY, WITH A "WARM" START



PRELIMINARY RESULTS

EXPERIMENT SETTINGS

Instances: Solomon (1987), first 25 customers + CTT typical jobs configuration

- Random (R)
- Clustered (C)
- Short time-windows (1)
- Long time-windows (2)

CTT job configurations:

- 7 second-half end-haulage
- 6 second-half pre-haulage

Decoupling:

- 3 complete end-haulage
- 1 complete pre-haulage

No Decoupling:

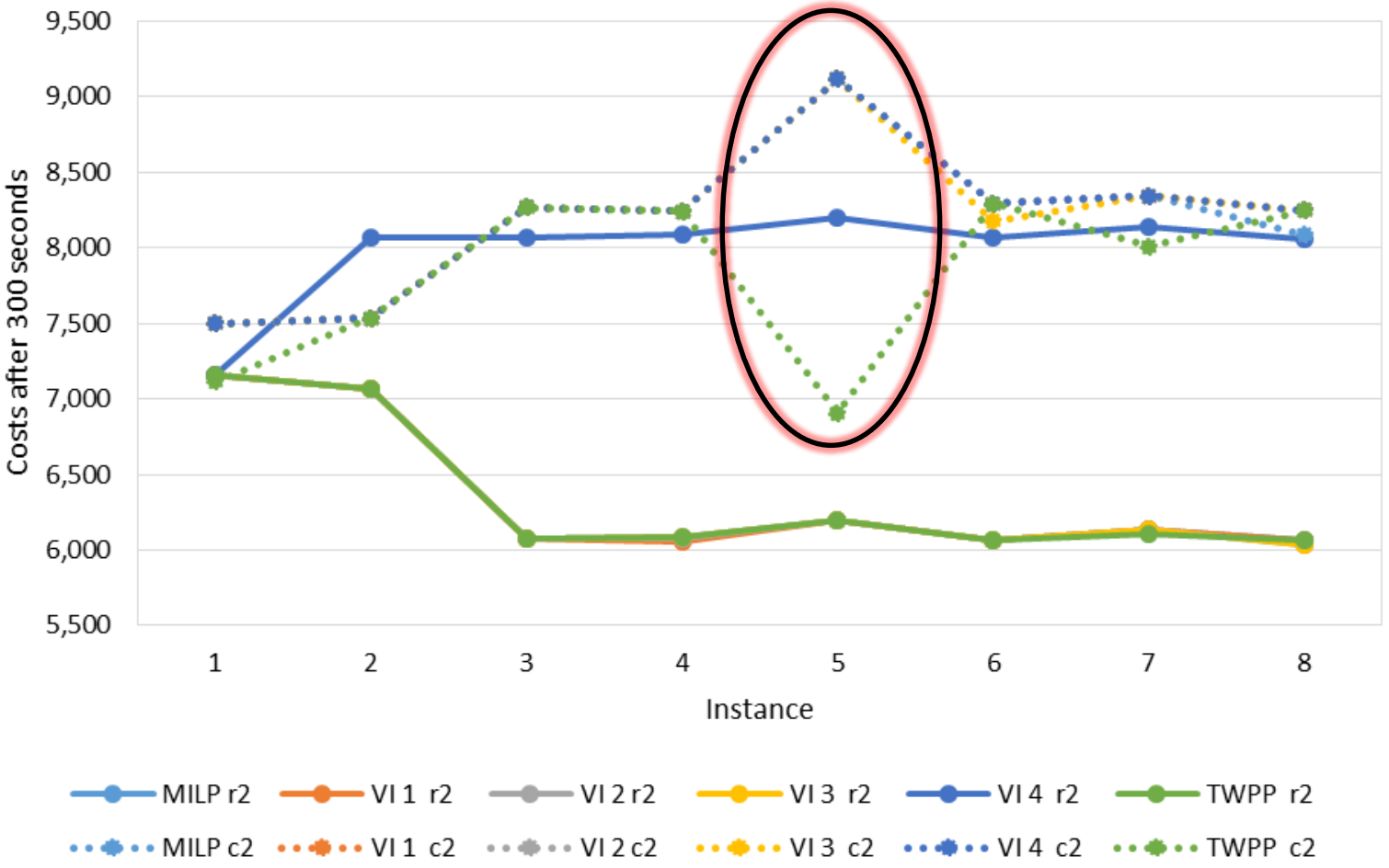
- 4 complete end-haulage
- 3 complete pre-haulage

Goal: ***shortly explore the performance of MILP enhancements and local-search operators, under different problem settings, and a warm start.***

Solver: CPLEX 12.6.3 (via the C API) with limit of 300 seconds.

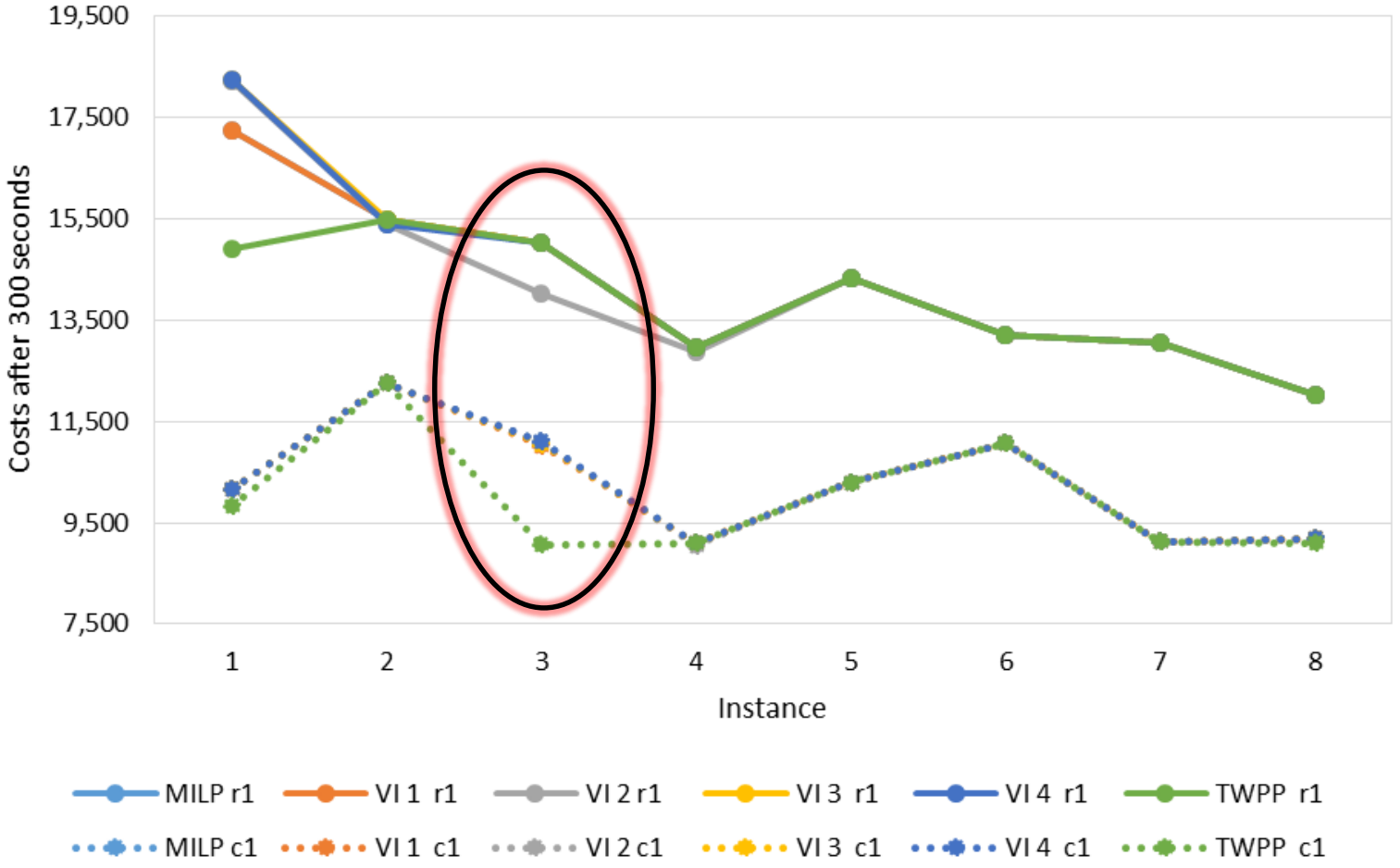
PRELIMINARY RESULTS: MILP ENHANCEMENTS

LONG TIME-WINDOWS



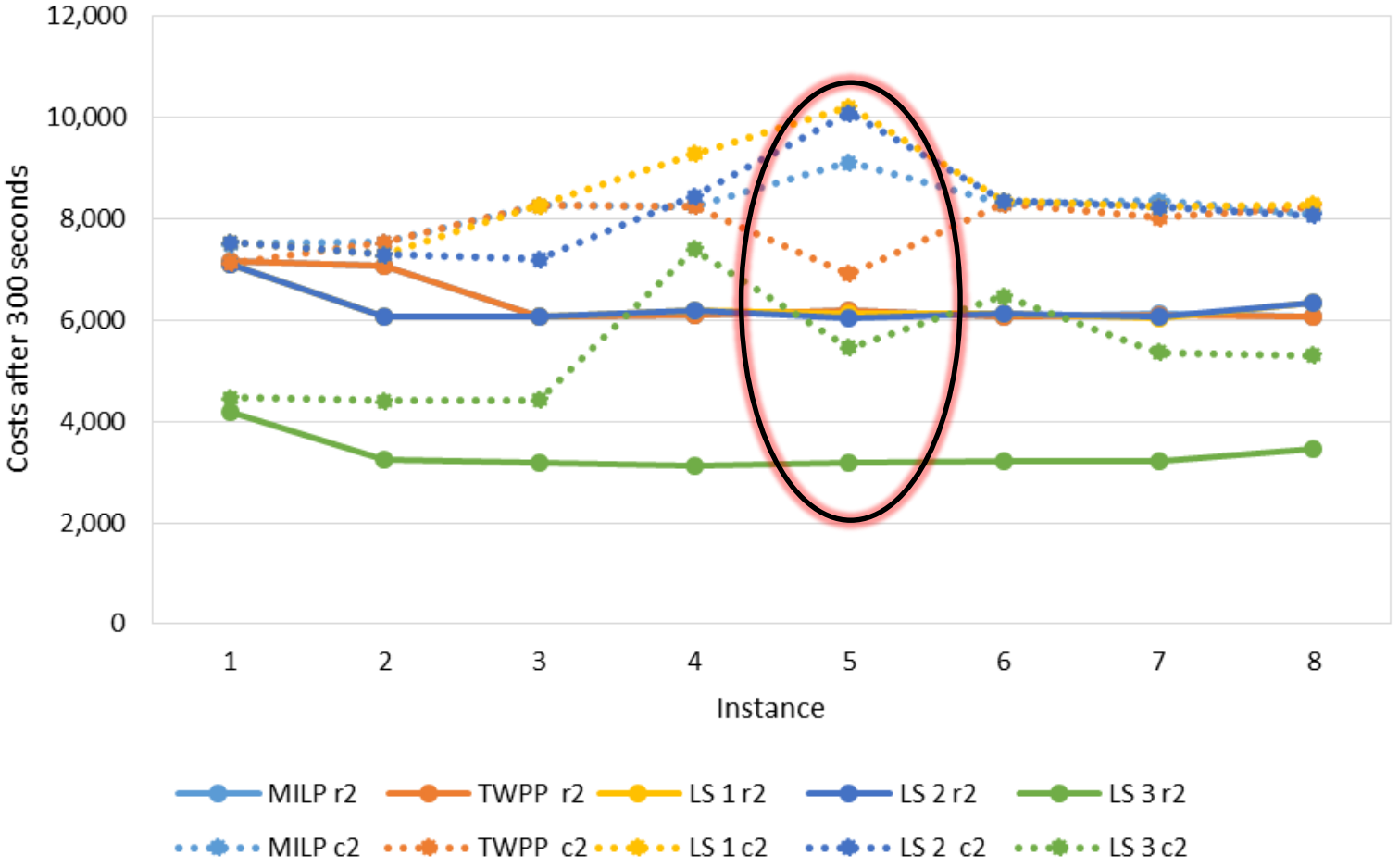
PRELIMINARY RESULTS: MILP ENHANCEMENTS

SHORT TIME-WINDOWS



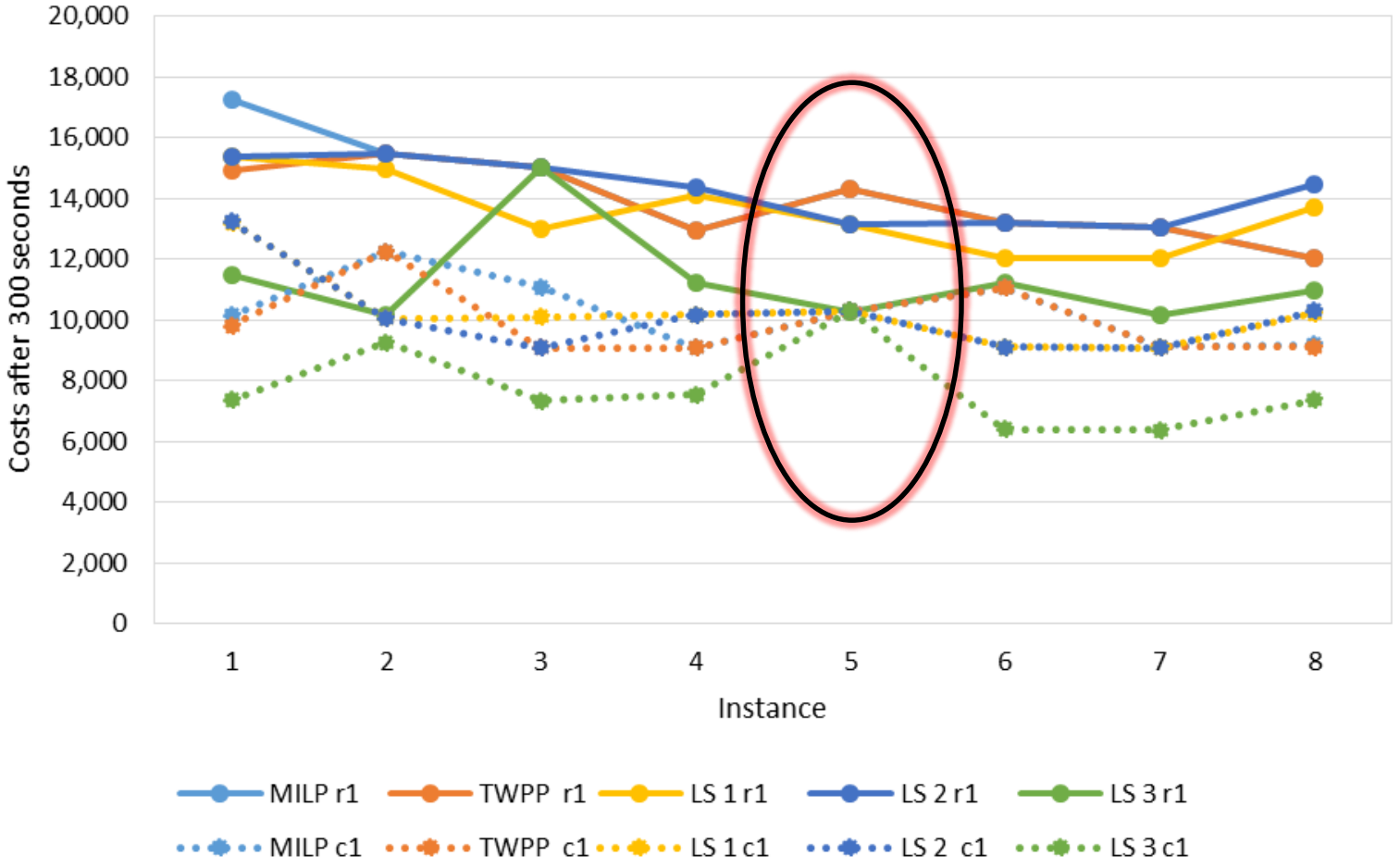
PRELIMINARY RESULTS: LOCAL-SEARCH OPERATORS

LONG TIME-WINDOWS



PRELIMINARY RESULTS: LOCAL-SEARCH OPERATORS

LONG TIME-WINDOWS



PRELIMINARY RESULTS: OBSERVATIONS

SOME INSIGHTS INTO OUR FTPDPTW MODEL

1. In most cases, a ***warm start***, even if expensive or infeasible, helps CPLEX to find a (good) integer solution quicker.

2. Of the MILP enhancements tested, the ***time-window pre-processing*** performed better overall than bounds on arcs between depots, bounds on trucks, and bounds on traveling distance.

3. Of the local-search operators tested, ***fixing an origin (or destination) for jobs with more than 2 origins (or destinations)*** performed better than fixing the use of trucks, fixing the number of jobs per truck, fixing customer-customer pairs.

WHAT TO REMEMBER

- Synchromodality, in terms of job and terminal flexibility, brings new cost-saving opportunities in pre- and end-haulage operations.
- We propose an FTPDPTW model for the pre- and end-haulage operations in a synchromodal network, and an ALNS-based framework for solving the dynamic problem.
- The benefits of selecting different pre-processing mechanisms and sets of local-search operators for different “states” should be further investigated.

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THANKS FOR YOUR ATTENTION!

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