Integration of Routing and Resource Allocation in Dynamic Logistics Networks

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Outline

- Problem Description
- Integration Strategies
- Experiment Design and Results
- Conclusion and Outlook

Problem Description

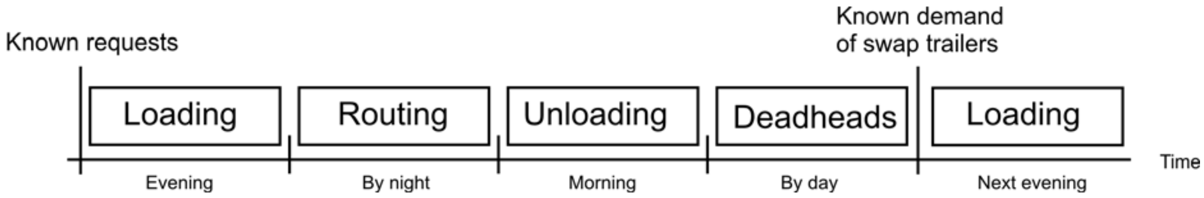
- Hub-and-spoke network
- Daily hub-to-hub transports
- By-passing other hubs is possible

- Charge carrier swap trailer (ST)
- One transportation request is one ST

- Truck trailer can transport at most two ST
- Sufficient number of ST
- Transport by 3rd party carriers paid for routes only

Problem Description

- Tasks
  - Routing of loaded ST
  - Allocation of empty ST



- Goals
  - Construction of distance minimal routes
  - Matching supply and demand of empty ST

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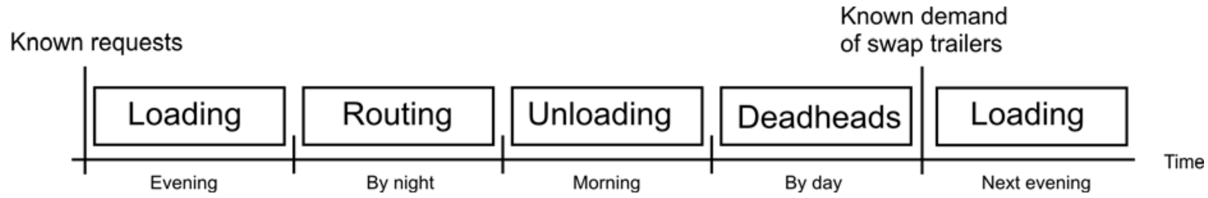


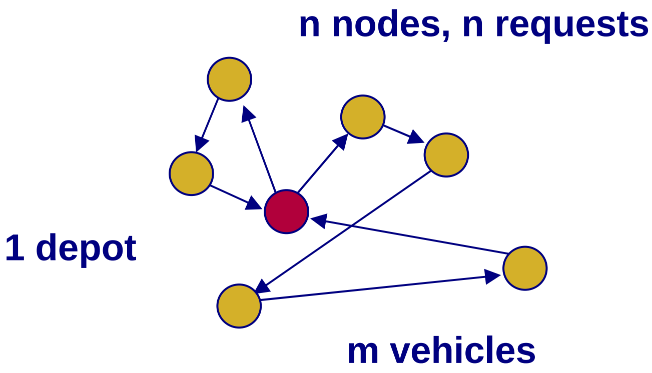
- Goals
  - Construction of distance minimal routes
  - Matching supply and demand of empty ST

- Choice concerning the distribution of ST
  - By explicit deadheads [Crainic et al.]
  - Entrainment in the routing phase (by-product)

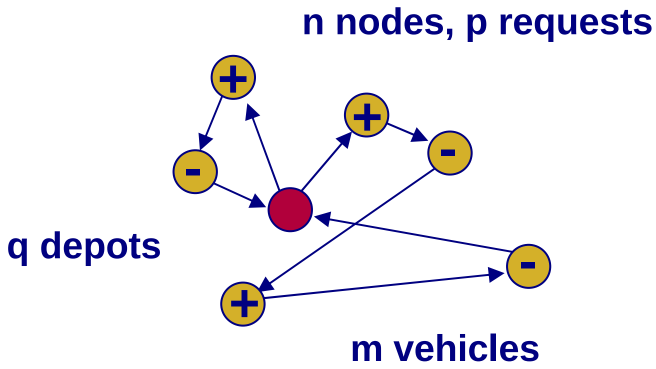
Crainic, T.G. ; Gendreau, M. ; Dejax, P.: Dynamic and stochastic models for the allocation of empty containers. In: Operations Research, 41(1):102–126, 1993.

Model Building – Vehicle Routing

- The Vehicle Routing Problem
  - Assignment decision
  - Sequence decision
  - Capacity constraints



- Special Pickup and Delivery Problem
  - Precedence constraints
  - Multi-depot
  - Multi-request per node
  - Multi-period

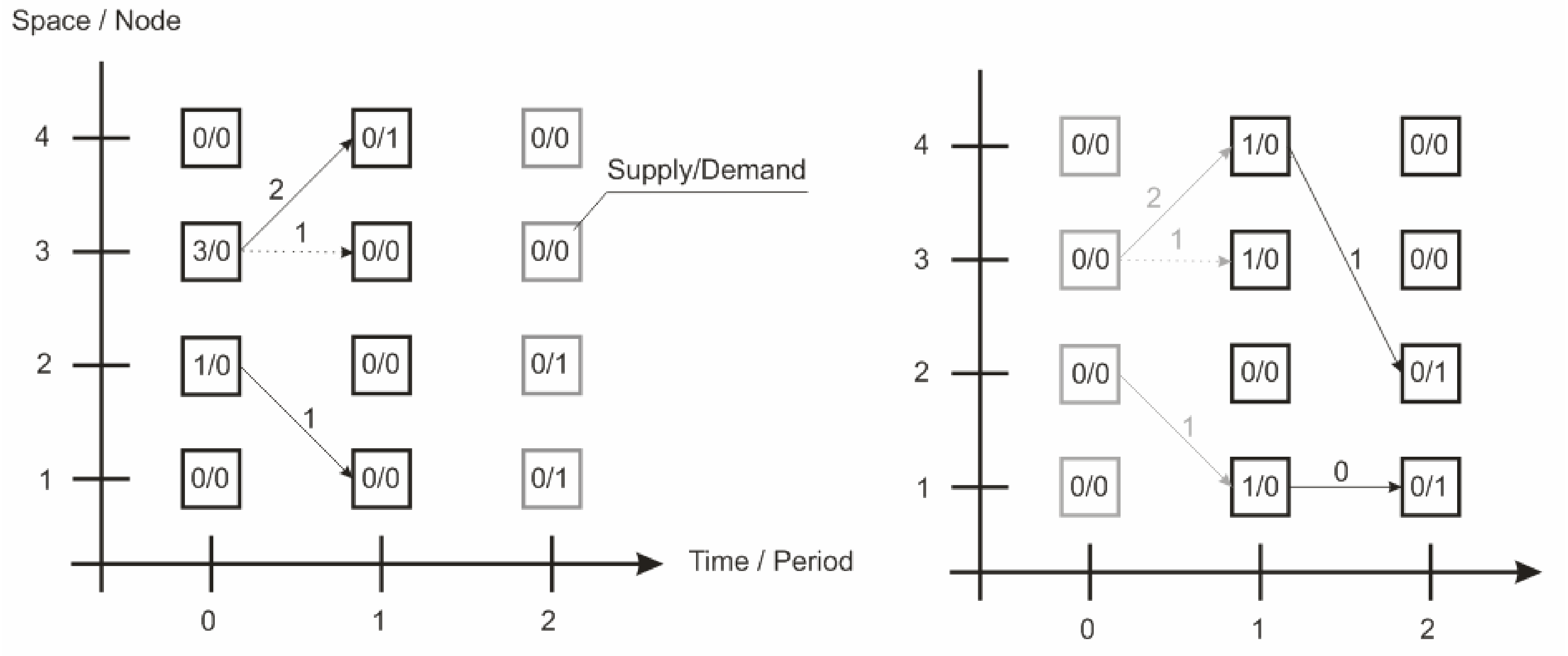


- Modeling: GPDP + modifications

Savelsbergh, M.W.P. ; Sol, M.: The General Pickup and Delivery Problem.
In: Transportation Science, 29(1):17-29, 1995.

Model Building – Resource Allocation

- Modeling as a Multi-Stage Transportation Problem



- Well known Transportation Problem
- Some extensions for the multi-stage property
  - E.g. third index for time and
  - Copy constraint for updating unused resources over time

Bookbinder, J.H. and Sethi, S.P.: The Dynamic Transportation Problem: A Survey. In: Naval Research Logistics Quarterly 27(1): 65-87, 1980.

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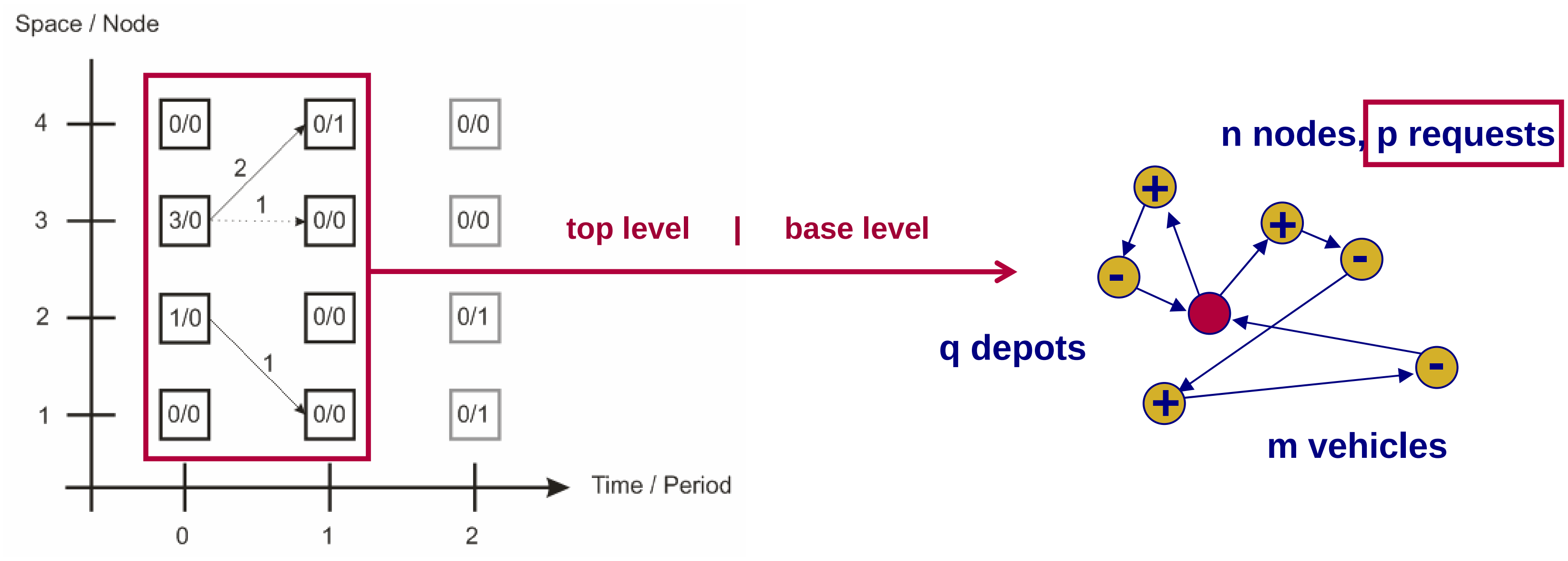
Functional Integration

- Solve the Transportation Problem

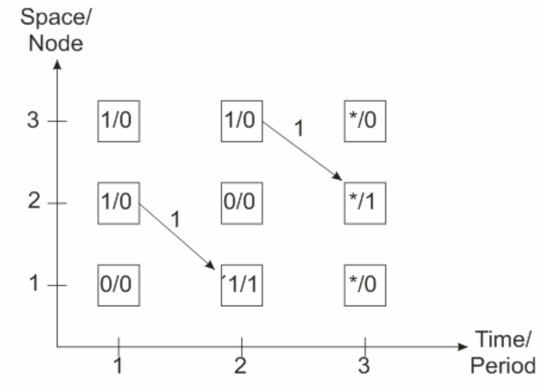


- Advantages
  - Tactical knowledge
  - Cost minimal total flows for deadheads
- Disadvantage
  - Transportation Problem biases the routing decision

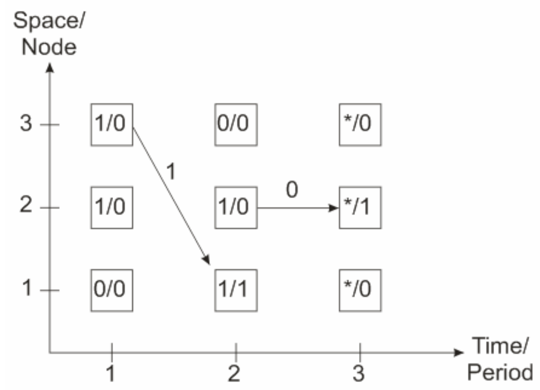
Discussion of the Approach

- Advantage
  - Successive one-period model 1)
  - Multi-period model 2) succeeds

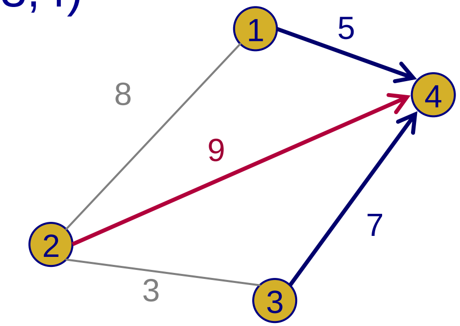
1)



2)



- Disadvantage
  - One transportation request: (2,4)
  - One allocation request: (1,4) or (3,4)



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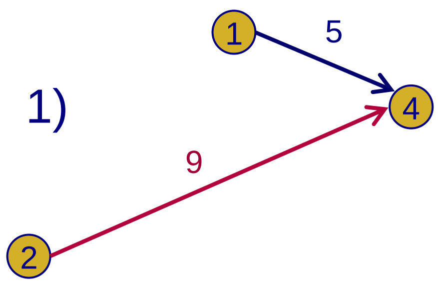

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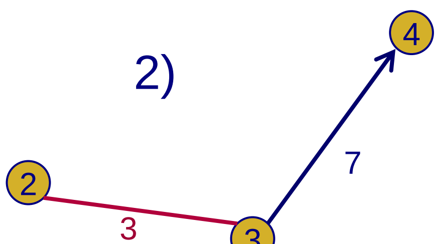


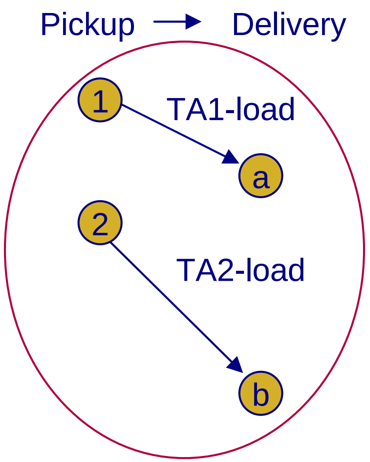
Deep Integration

- Choosing OD pairs on the base level

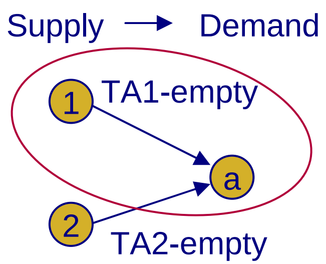
Set-Partitioning formulation

Tasks T	**Transportation requests**			
	TA1-load	TA2-load	TA1-empty	TA2-empty
b1	**1**	**0**	**0**	**0**
b2	**0**	**1**	**0**	**0**
b3	**0**	**0**	**1**	**1**

(TA1-load, TA2-load, TA1-empty)
(TA1-load, TA2-load, TA2-empty)



$$\sum_{i \in R \cup D} x_{li}^{k} = \sum_{i \in R \cup D} x_{il}^{k} = z_{a}^{k} * y_{a} \longleftarrow \sum_{a \in TA} e_{ab} y_{a} = 1$$



- Selection vector *y* into constraint of the PDP
  - a truck enters or leaves a node *l*
  - if there exists a request *a*
  - for this vehicle *k*
  - and this requests is chosen by the set partitioning constraint

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b2	**0**	**1**	**0**	**0**
b3	**0**	**0**	**1**	**1**

→ (TA1-load, TA2-load, TA1-empty)
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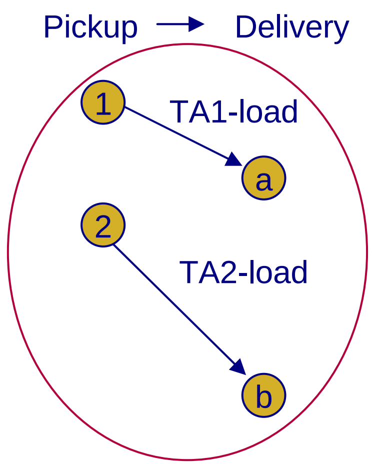

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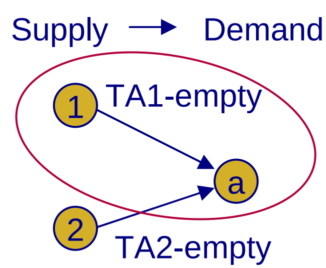

- Advantage
  - Implicit selection of OD for deadheads (synergies)
- Disadvantage
  - Solution for one period only (neglects the long term problem)
  - Extensive model ist difficult to solve

Comparison of the flow sheets

- Meta-heuristic solution method LNS for routing

Flow sheet – Functional Integration

Solve TP using CPLEX;

while (periods p)

$TA_p = TA_p$ + Get requests(p);

s = Init solution();

$s_{best} = LNS(s);$

Update swap trailers(s_{best});

endwhile

Flow sheet – Deep Integration

while (periods)

TA_{empty} = *Empty request sets();*

// get one request per set

s = Init solution(TA_{empty});

$s_{best} = LNS(s, TA_{empty});$

Update swap trailers(s_{best});

endwhile

Ropke, S. and Pisinger, D.: An adaptive large neighborhood search heuristic for the pickup and delivery problem with time windows. In: *Transportation Science*, 40(4) 455-472, 2006.

Huth, T. and Mattfeld, D.: Integration of routing and resource allocation in a dynamic logistics network. In: submitted to Transportation Research Part C: Emerging Technologies, 2007.

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Experiment Design

- 12 VRPTW instances from Solomon (25, 50, 100 nodes)
- Extensions of these instances taken from Nanry / Barnes
- Tour duration time are used
- No service times are considered
- No time windows are considered

- Rolling planning horizon with
  - 20 periods and 25/50/100 jobs per period
  - Distribution of pickup and delivery locations
    - Uniform
    - Normal
    - Normal (smaller standard deviation)
- Resources: 3 swap trailers per node initial configuration

Nanry, W.P. ; Barnes, W.: Solving the pickup and delivery problem with time windows using reactive tabu search. In: *Transportation Research Part B*, 34:107–121, 2000.

Solomon, M.M.: Algorithms for the vehicle routing and scheduling problems with time window constraints. In: *Operations Research*, 35(2)254-265,1987.

Computational Results - Entrainments

Distribution	msTP	0. Sequential planning		1. Deep integration		2. Functional integration	
		Distance	Deadhead	Distance	Deadhead	Distance	Deadhead
Uniform	2.789	478.061	20.450	480.077	9.265	461.135	0
Normal	4.778	540.698	72.831	516.565	20.935	471.562	0
Normal (ssd)	9.333	602.510	141.374	552.456	54.537	470.037	0
Sum	**16.900**	**1.621.269**	**234.655**	**1.549.098**	**84.737**	**1.402.734**	**0**

- Distribution determines deadheads
- (0) and (1) need plenty more deadheads than the optimal flow suggested
- Allocation requests performed by deadheads
  - (0): all
  - (1): some
  - (2): none (all by detours and entrainments)
- Integration with uniform distribution does not make much sense (no allocation)
- (2) outperforms (0) by 13.5% and (1) outperforms (0) by 5%

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Conclusion

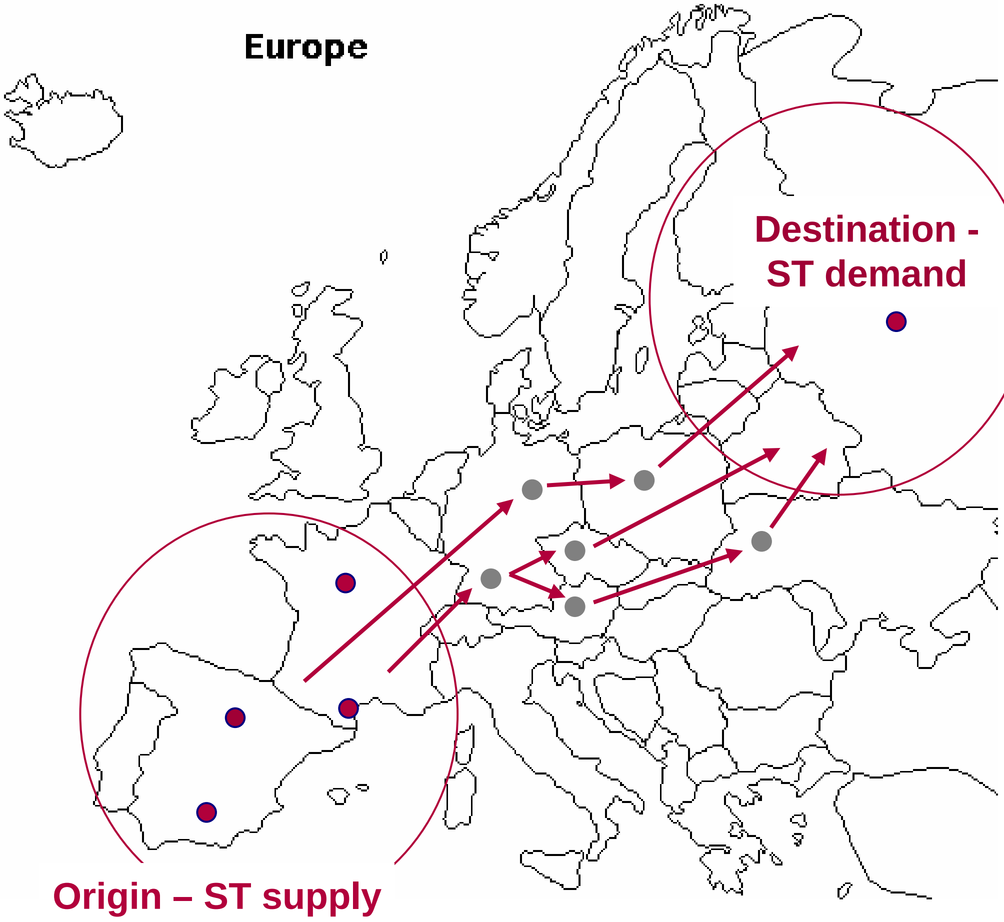
- Real-world vehicle routing and allocation problem
  - Description
  - Model building
- Integration of different planning levels
  - Deep integration: GPDP with selection component (SP)
  - Functional integration: Transportation Problem communicates to GPDP
- Results
  - Integration approaches are beneficial
  - Functional integration outperforms deep integration, because:
    - Tactical knowledge (FI)
    - Myopic solutions (DI)

Outlook – the next steps …

- Computation of more experiments
- Improved neighborhood definition

- Evaluation of hybrid approaches
  - Focus on tactical planning:
    Degrees of freedom (selection)
    for the routing problem
  - Focus on operational planning:
    Anticipation of future requests

- Considering stochastic data
- Stochastic programming



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- Stochastic influences

Thank you
for your attention!

Questions?