ANTICIPATORY FREIGHT SCHEDULING IN SYNCHROMODAL TRANSPORT

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Technische Universität Braunschweig
Braunschweig, Germany
Background and Motivation

Long-haul Round-trip Transport

Long-haul Multi-transfer Transport

Multi-terminal Drayage Transport

Integrated Long-haul and Drayage Transport

Raising Awareness Through Serious Games

What to Remember
BACKGROUND – SYNCHROMODALITY
WHAT IS SYNCHROMODAL TRANSPORT?

*Source of video: Dutch Institute for Advanced Logistics (DINALOG) www.dinalog.nl

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ANTICIPATORY SCHEDULING IN SYNCHROMODALITY
FLEXIBILITY IN *MODE*, *PATH*, AND *TIME* OF TRANSPORT

For LSPs, the flexibility of synchromodal transport:

1. **Provides new consolidation opportunities**
2. **Requires network-wide and multi-period performance focus**

*Source of artwork: European Container Terminals (ECT) – The future of freight transport (2011).*
MOTIVATION – LOGISTICS SERVICE PROVIDER IN TWENTE
TRANSPORT OF CONTAINERS TO/FROM THE HINTERLAND

*Source of artwork: Combi Terminal Twente B.V. www.ctt-twente.nl
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ANTICIPATORY SCHEDULING IN SYNCHROMODALITY
FOUR PERSPECTIVES FOR A MULTI-MODAL TRANSPORT NETWORK


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Balance the consolidation and postponement of freight transport through *time*.

*Source of artwork: European Container Terminals (ECT) – The future of freight transport (2011).*
I – LONG-HAUL ROUND-TRIP TRANSPORT

OUR APPROACH

1. A Markov Decision Process (MDP) model to capture the dynamic and stochastic nature of the problem.

2. An Approximate Dynamic Programming (ADP) heuristic to approximate the costs of postponement in large instances.
I – LONG-HAUL ROUND-TRIP TRANSPORT

NUMERICAL RESULTS

Figure 2.3: Learned values (left) and average cost performance (right) of the ADP algorithm for the different sets of features for State 2 of the single-trip problem.

Table 3.4: Confidence intervals (at 95%) of the difference between the benchmark policy and the ADP policy.

<table>
<thead>
<tr>
<th>State</th>
<th>$I_1^c$</th>
<th>$I_2^c$</th>
<th>$I_3^c$</th>
<th>$I_1^c$</th>
<th>$I_2^c$</th>
<th>$I_3^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>[-7.6%, -4.8%]</td>
<td>[-9.6%, -7.5%]</td>
<td>[-10.3%, -8.4%]</td>
<td>[-6.1%, -4.9%]</td>
<td>[-1.3%, 0.0%]</td>
<td>[-5.9%, -4.5%]</td>
</tr>
<tr>
<td>C2</td>
<td>[-9.7%, -8.4%]</td>
<td>[-13.1%, -11.6%]</td>
<td>[-4.8%, -3.3%]</td>
<td>[-3.6%, -1.8%]</td>
<td>[-1.2%, 0.1%]</td>
<td>[-11.6%, -10.4%]</td>
</tr>
<tr>
<td>C3</td>
<td>[-2.7%, -1.2%]</td>
<td>[-3.2%, -1.7%]</td>
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<td>[-3.8%, -2.4%]</td>
<td>[0.5%, 1.7%]</td>
<td>[-7.7%, -6.7%]</td>
</tr>
<tr>
<td>C4</td>
<td>[-16.0%, -13.8%]</td>
<td>[-26.5%, -24.6%]</td>
<td>[-6.2%, -4.1%]</td>
<td>[-12.5%, -11.2%]</td>
<td>[-2.2%, 0.7%]</td>
<td>[-8.4%, -7.6%]</td>
</tr>
<tr>
<td>C5</td>
<td>[-15.9%, -14.3%]</td>
<td>[-6.0%, -0.9%]</td>
<td>[10.5%, 8.8%]</td>
<td>[-26.5%, -25.3%]</td>
<td>[1.0%, 0.1%]</td>
<td>[-10.3%, -9.2%]</td>
</tr>
<tr>
<td>C6</td>
<td>[0.5%, 2.1%]</td>
<td>[-1.1%, -0.9%]</td>
<td>[-4.5%, -3.1%]</td>
<td>[-11.1%, -10.0%]</td>
<td>[-2.6%, -1.4%]</td>
<td>[-8.2%, -7.3%]</td>
</tr>
<tr>
<td>C7</td>
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<td>[-4.3%, -3.0%]</td>
<td>[-25.0%, -23.5%]</td>
<td>[-0.6%, 0.4%]</td>
<td>[-12.2%, -9.8%]</td>
<td>[-7.9%, -6.8%]</td>
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<tr>
<td>C8</td>
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<td>[-2.5%, -1.6%]</td>
<td>[-7.5%, -6.7%]</td>
<td>[-0.9%, -0.2%]</td>
<td>[-3.7%, -2.9%]</td>
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<tr>
<td>C9</td>
<td>[-1.5%, -0.3%]</td>
<td>[1.8%, 2.8%]</td>
<td>[-5.4%, -3.5%]</td>
<td>[-11.4%, -10.7%]</td>
<td>[3.9%, 5.4%]</td>
<td>[-7.9%, -7.2%]</td>
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</tbody>
</table>
I – LONG-HAUL ROUND-TRIP TRANSPORT

THE PROBLEM


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II – LONG-HAUL MULTI-TRANSFER TRANSPORT

THE PROBLEM

Balance the consolidation and postponement of freight transport through *time and space*.


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II – LONG-HAUL MULTI-TRANSFER TRANSPORT

OUR APPROACH

1. An MDP model and a Mixed-Integer Linear Program (MILP) to capture the time-space evolution of the transport network.

2. An ADP heuristic with Reinforcement Learning constructs to solve the exploration vs. exploitation dilemma.
II – LONG-HAUL MULTI-TRANSFER TRANSPORT

THE PROBLEM


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Balance the immediate routing costs and the *terminal assignment* costs.

*Source of artwork: European Container Terminals (ECT) – The future of freight transport (2011).*
III – MULTI-TERMINAL DRAYAGE TRANSPORT

OUR APPROACH

1. **A Mixed Integer Linear Program (MILP)** to represent the rich vehicle routing problem and terminal assignment problem.

2. **A Matheuristic (MH) with iterative MILP adaptations (polytope cuts)** to solve the MILP for large instances.
Table 5.2: Total costs for various MILP adaptations

<table>
<thead>
<tr>
<th>Instances</th>
<th>BH</th>
<th>MILP</th>
<th>VIs</th>
<th>TWPP</th>
<th>MHO 1</th>
<th>MHO 2</th>
<th>MHO 3</th>
</tr>
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<tbody>
<tr>
<td>C1</td>
<td>77,960</td>
<td>77,926</td>
<td>77,960</td>
<td>76,924</td>
<td>76,829</td>
<td>77,926</td>
<td>75,189</td>
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<tr>
<td>C2</td>
<td>52,904</td>
<td>52,882</td>
<td>52,904</td>
<td>52,049</td>
<td>51,841</td>
<td>52,078</td>
<td>50,802</td>
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<tr>
<td>R1</td>
<td>111,087</td>
<td>111,078</td>
<td>110,904</td>
<td>107,649</td>
<td>107,254</td>
<td>107,647</td>
<td>107,736</td>
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<tr>
<td>R2</td>
<td>50,500</td>
<td>50,435</td>
<td>50,500</td>
<td>50,497</td>
<td>50,255</td>
<td>50,500</td>
<td>50,378</td>
</tr>
</tbody>
</table>

Figure 5.3: Comparison FCs at last stage

Figure 5.4: Performance of best FC per stage
III – MULTI-TERMINAL DRAYAGE TRANSPORT

THE PROBLEM


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Balance long-haul and drayage transport network-wide through time.


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A simulation-based integration of the ADP algorithm and the matheuristic to capture the recursive relation between drayage operations and long-haul transport.

**Figure 6.3**: Components of the recursion between drayage and long-haul decisions

**Figure 6.4**: Proposed solution methods to the integrated scheduling model
IV – INTEGRATED LONG-HAUL AND DRAYAGE

NUMERICAL RESULTS

Table 1: Percentage difference with the benchmark in normal drayage-cost setup

<table>
<thead>
<tr>
<th>Instance</th>
<th>R-P-U</th>
<th>R-P-B</th>
<th>R-E-U</th>
<th>R-E-B</th>
<th>C-P-U</th>
<th>C-P-B</th>
<th>C-E-U</th>
<th>C-E-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-haul Costs</td>
<td>-10%</td>
<td>-14%</td>
<td>-63%</td>
<td>-65%</td>
<td>-14%</td>
<td>-13%</td>
<td>-63%</td>
<td>-65%</td>
</tr>
<tr>
<td>Drayage Costs</td>
<td>17%</td>
<td>18%</td>
<td>33%</td>
<td>32%</td>
<td>16%</td>
<td>12%</td>
<td>21%</td>
<td>22%</td>
</tr>
<tr>
<td>Long-haul Utilization</td>
<td>4%</td>
<td>1%</td>
<td>-55%</td>
<td>-55%</td>
<td>5%</td>
<td>0%</td>
<td>-56%</td>
<td>-55%</td>
</tr>
<tr>
<td>Pre- haulage Closest</td>
<td>-21%</td>
<td>-27%</td>
<td>-82%</td>
<td>-81%</td>
<td>-37%</td>
<td>-35%</td>
<td>-81%</td>
<td>-82%</td>
</tr>
</tbody>
</table>
ANTICIPATORY SCHEDULING IN SYNCHROMODALITY
FOUR PERSPECTIVES FOR A MULTI-MODAL TRANSPORT NETWORK


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RAISING AWARENESS THROUGH SERIOUS GAMES
WWW.TRUCKSANDBARGES.NL
We study four different perspectives on scheduling freight in synchromodal transport, and propose anticipatory methods to take advantage of the flexibility in synchromodality.

- **Anticipating on future scheduling decisions** in synchromodal transport pays off the most with pre-announced freights that have long-time windows, and the least with urgent freights and balanced networks.

- **Integrating anticipatory decisions** of drayage and long-haul transport improves the performance of the network as a whole, but might sacrifice the performance of one of the processes.
THANKS FOR YOUR ATTENTION!

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