Principles of Synchronous Railway Yard Simulation with Integrated Movement Scheduling

Benno Hütter, Manfred Gronalt
Boku University Vienna, Institute for Production and Logistics

IAROR - RailTokio 2015
24.03.2015
SimShunt  SIMULATION OF SHUNTING FACILITIES

Agenda

- Simulation Model Approach
- SimShunt – structure
- Implementation and results
- Use, application and benefits
Simulation approach

- Development of a **Simulation Tool for Capacity Analysis** of Shunting Yards
- Timetable and characteristics of incoming Trains should dynamically trigger the whole production process (Inspection, Interchange decision, Loosening of couplings, Humping, classification track assignment, Bypass processes, Formation acc. to outbound train schemes, Traction unit coupling, Breaketests, Departure)
- Framework should be able to cover different shunting facilities and yard types (flat yards, hump yards ..)

*Deadlock-free model for analysis of yard performance analysis*
Inclusion of shunting movements

- Solution for routing and dispatching

Inclusion of operational strategies

- Synchronous decision integration

- Solution for arising **deadlock problem**

*None of the known deadlock avoidance strategies of synchronous railway line simulation is suitable for shunting yard simulation*
Deadlocks can arise due to:

- **Conflicting resource allocation sequence (insufficient token decisions)**
  - Is possible to handle
- **Conflicts during synchronous movement execution (classic railway simulation deadlock of synchronous simulation models of line operation)**
  - High number of interdependent movements
  - Train length dependent track occupation
  - Reversal movements
  - Almost all tracks of bidirectional usage
  - Known strategies for deadlock avoidance would lead to complete route reservation in advance (with capacity loss in comparison to real operation)
SimShunt structure

Prevent simulation system from circular-wait structures

- Asynchronous Movement Scheduling
  - Track layout divided into capacity tracks and a connecting track network.
  - No Stops in between the connecting track network allowed.
  - Uncertainties in movement execution cannot be considered.
  - Movements start and end on capacity tracks in deadlock safe states.
  - Deadlock safeness has to be guaranteed by a sequence control unit providing a ...
  - Rigorous capacity track, and dependent resource allocation system.

Deadlock issue is primarily reduced to a capacity track allocation problem
SimShunt SIMULATION OF SHUNTING FACILITIES

SimShunt structure – Routing and scheduling

- Routing graph design (described in paper)
  - Based on shunting path lists
  - A weighted digraph with 3 subsets of arcs
- Dynamic Route calculation
  - Modified k-Shortest Path algorithm
- Asynchronous Movement Scheduling
  - Mixed Integer Programming Model
  - Redispacht of waiting movement requests
  - Train movement prioritization
SimShunt SIMULATION OF SHUNTING FACILITIES

SimShunt structure
Central Marshalling yard Vienna

nominal hump capacity of 6100 Waggon / 24hours (1986)

1 mio. Squaremeters, built 1978-1986

<table>
<thead>
<tr>
<th>Yard Type</th>
<th>count</th>
<th>min length [m]</th>
<th>max length [m]</th>
<th>sum [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving Yard</td>
<td>15</td>
<td>694</td>
<td>929</td>
<td>11354</td>
</tr>
<tr>
<td>Classification Bowl</td>
<td>48</td>
<td>606</td>
<td>953</td>
<td>36374</td>
</tr>
<tr>
<td>Departure Yard</td>
<td>8</td>
<td>666</td>
<td>940</td>
<td>6607</td>
</tr>
<tr>
<td>Sorting Bowl</td>
<td>12</td>
<td>508</td>
<td>575</td>
<td>6403</td>
</tr>
</tbody>
</table>

Central Marshalling Yard Vienna - track capacities
## SimShunt SIMULATION OF SHUNTING FACILITIES

### Results - Volume

<table>
<thead>
<tr>
<th>Inbound trains</th>
<th>count</th>
<th>weight[t]</th>
<th>length[m]</th>
<th>wagons</th>
<th>technical inspections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturday</td>
<td>51</td>
<td>50654</td>
<td>24818</td>
<td>1371</td>
<td>3</td>
</tr>
<tr>
<td>Sunday</td>
<td>21</td>
<td>23200</td>
<td>9549</td>
<td>532</td>
<td>0</td>
</tr>
<tr>
<td>Monday</td>
<td>75</td>
<td>70961</td>
<td>30622</td>
<td>1707</td>
<td>14</td>
</tr>
<tr>
<td>Tuesday</td>
<td>101</td>
<td>89702</td>
<td>41586</td>
<td>2323</td>
<td>16</td>
</tr>
<tr>
<td>Wednesday</td>
<td>98</td>
<td>89641</td>
<td>38805</td>
<td>2151</td>
<td>16</td>
</tr>
<tr>
<td>Thursday</td>
<td>105</td>
<td>97083</td>
<td>39193</td>
<td>2185</td>
<td>18</td>
</tr>
<tr>
<td>Friday</td>
<td>101</td>
<td>95412</td>
<td>38196</td>
<td>2099</td>
<td>17</td>
</tr>
</tbody>
</table>

### Inbound Volume

<table>
<thead>
<tr>
<th>Trains</th>
<th>single group</th>
<th>multigroup</th>
<th>fineordering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturday</td>
<td>59</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Sunday</td>
<td>22</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Monday</td>
<td>50</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Tuesday</td>
<td>82</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Wednesday</td>
<td>86</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Thursday</td>
<td>83</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Friday</td>
<td>84</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

---

17.04.2015
Humped railcars per hour (1 week)
SimShunt  SIMULATION OF SHUNTING FACILITIES

Results

Train departure deviation [1 day]

+/- Deviation_Real [min]

+/- Deviation_Sim [min]
Classification Bowl Fillrates and Formation Indicators (24h)

- AdditionalTrainPartsToCollect x 10
- CB-NumberOfFormationMoves[count] x10
- CB-NumberOfIntegratedPreFormationMoves x10
- CB-FillRateNbOccupiedTracks[count/count]
- CB-Fillrate[m/m]
- CB-NbTrainsGatheringBeforeFormation[count]
- CB-NbTrainPartsConnectedGatheringBeforeFormation[count]
- CB-NbLockedTracksBeforeFormation[count]
Benefits and limitations

Benefits
- Easy scenario variation (parameter variation)
- Supports sensitivity analysis
- Facilitation of comparative simulation studies
- Deadlock free model structure supports long term analysis
- Consideration of operational strategies as critical influencing parameters

Limitations
- Limited consideration of movement uncertainties
- Synchronous decision integration is limited to the algorithmic feasibility
- Degree of freedom of certain decisions may be limited in comparism to the real case to reduce simulation system complexity.
• Assessment of infrastructural changes, or needs
• Analysis of process optimization issues
• Capacity analysis under predefined conditions
• Operational strategy development
• Potential and risk assessment of operational changes
• Increment of planning certainty degree
Conclusion

• Asynchronous movement scheduling is one way to provide a **deadlock free railway simulation** (for shunting facilities) with synchronous decision integration.

• The proposed **routing graph** is suitable for generating valid shunting movements including train length dependent reversals.

• Algorithmic decision integration turns out to be a challenging issue but offers a broad field of model application in terms of **system analysis** and **strategy development and evaluation**.

• The proposed model structure could serve as a **testing environment for online optimization Algorithms** (e.g. for solving the TMP)
Thank you for your attention!