Condition Based Logistics: Calculation of Process Capacity

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Outline

1. CBM Business Problem
2. Logistic Context
3. Solution Method
4. Implementation
5. Results
6. Further Research and Development
Condition Based Maintenance

- Maintenance jobs are triggered by condition of individual components
  - Technically
    - preventive maintenance
  - Logistically:
    - Planned inspections
    - Unplanned replacements and repairs
    - Significant variation in workload

- Train operation versus maintenance services
  - Train operation schedules train *types*
  - Maintenance services schedules trains as *physical units*
Business Problem

- To what extent can the rail infrastructure accommodate CBM?
  - Do shunting yards have sufficient process capacity?
  - What is the effect of modern train design on it?
- How to assess infrastructure modifications?
- Obtain an objective quantitative method to calculate process capacity
Today’s Practice

- Capacity is expressed in track or train length only
  - Process capacity emerges from daily practice
  - Result depends strongly on individual staff skills
- Required to take into account
  - Shunting and combining trains
  - Service and maintenance jobs
  - Access to dedicated platforms and machines
- No computational method available for overall process capacity
  - Poor support for investment decisions
Logistic Context

Input Specification → Time Table → Output Specification

Physical Train Matching

Maintenance Management

Train Condition → Work Package

Shunting & Service Site

Infrastructure Design → Service Staff

Train Sets

Railway Operations

Service Staff → Train Sets
### Daily Logistic Problem (Example)

<table>
<thead>
<tr>
<th>Arrivals</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Departures</th>
</tr>
</thead>
<tbody>
<tr>
<td>21:10 A4</td>
<td>I</td>
<td>I</td>
<td>C</td>
<td>A4:05:21</td>
</tr>
<tr>
<td>A6</td>
<td>I</td>
<td>C</td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>21:26 B6</td>
<td>C</td>
<td>R</td>
<td>I</td>
<td>B4:05:43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21:54 B4</td>
<td>C</td>
<td>C</td>
<td>I</td>
<td>B4:06:01</td>
</tr>
<tr>
<td>B4</td>
<td>I</td>
<td>C</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>B4</td>
<td></td>
<td>I</td>
<td></td>
<td>B4</td>
</tr>
<tr>
<td>22:06 A6</td>
<td>I</td>
<td>I</td>
<td>R</td>
<td>A6:06:14</td>
</tr>
<tr>
<td>A6</td>
<td>C</td>
<td>C</td>
<td>W</td>
<td></td>
</tr>
</tbody>
</table>

- **A4, A6**: Train type
- **B4, B6**: Train type
- **I, R, C, W**: Job Type

**Condition Based Logistics: Calculation of Process Capacity**
Site Layout (Example)
On-site process planner has to solve every day a different logistic problem, taking into account:
- Site characteristics
- Resources availability
- Process regulations

Process capacity depends on the planner’s ability to solve these problems in practice.

Core problem is planning:
- Shunting (Routing Problem, Rush Hour Problem)
- Parking (Multi-Knapsack Problem)
- Services (Resource Constrained Multi-Project Scheduling Problem)
- Splitting and combining of trains
- Mapping of incoming trains to outgoing trains

Process capacity reflects maximum work package of shunting and service jobs for which feasible plans can be found.
Capacity Measure Dimensions

- Trade off between number of trains and all services provided
- Process capacity measure should be multi-dimensional: (number of trains, fleet composition, job_type_W%, job_type_C%, ...)

![Diagram showing feasible combinations of number of trains and percentage of trains requiring job type W. The Pareto front is indicated, showing the trade-off between these two factors.](image)
Definition

The process capacity of a shunting yard is the Pareto front of work package parameters for which a feasible plan can be found (within a specified amount of time) with respect to the available resources.
Process Capacity

Definition

The process capacity of a shunting yard is the Pareto front of distribution parameters that describe work packages such that for at least a specified percentage of these packages a feasible plan can be found (within a specified amount of time) with respect to the available resources.
Pareto Front Analyzer

- Pareto Front Analyzer
- Database
- Instance Generator
- Constraint Checker
- Planning Algorithm

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Planning Algorithm

- Modular fit into Pareto Front Analyzer
- Up-till now three approaches
  - Flexible Flow Shop (heuristic) → Shunting (exact)
  - Resource Constrained Schedule (heuristic) → Shunting (exact)
  - Monolithic (heuristic)
    - Single initial solution (resource feasible, not time feasible)
    - Simulated annealing
Shunting: Train Repositioning Makes the Difference

![Graph showing number of feasible solutions against number of train units]

- **SA**
- **SA w.o. repositioning**
- **OPG**

**Axes:**
- Y-axis: Number of feasible solutions
- X-axis: Number of train units

**Legend:**
- Blue line: SA
- Green line: SA w.o. repositioning
- Red line: OPG
Computational Results: Effect of Job Type W Ratio

Impact of Service Job Type W on Maximum Number Trains at site kBkh

- No Services Applied
- 20% Service Job Type W - Number of Tracks = 1
- 40% Service Job Type W - Number of Tracks = 1
Computational Results: Effect of Job Type C Team Size

Impact of Service Job Type C on Maximum Number Trains at site kBkh

- No Services Applied
- 100% Service Job Type C - Team Size = 8
- 100% Service Job Type C - Team Size = 4
Further Research & Development

- Compare systematically with human planners’ performance
- Improve and extend planning algorithms
- Better understanding of influencing factors
  - site layout
  - logistic problem characteristics
  - applied heuristics
- Empirical research to obtain more data on process variations and correlations
Thanks for Your Attention! Any Questions?