FMCG scheduling

Martijn van Elzakker

EWO meeting, March 2011
Outline

- Problem Overview
- Modeling Approach
- Results
- Future Work
Problem overview

Stage 1
- Mixing of products
- Processing

Intermediate Stage
- Intermediate Storage
- Maturing

Stage 2
- Packing

Product type 1
- PACK

Product type 2
- PACK

All products
- MIX
Main Challenge

- Large computational times
  - Intermediate inventory

1. Limited storage capacity ➔ Many mixer switches
   ➔ Many periods ➔ Large models

   - Considerably more storage tanks than mixers and packers
     - Model size largely determined by storage stage
Dedicated time slots

1. Limited Storage ➔ Many Periods ➔ Large Models
   - Observation: Almost never two consecutive mixing runs of the same product class (same packer)
   - Dedicate product types to periods ➔ Smaller model

   ▪ Empty periods ensure flexibility
2. Model size determined by # of tanks

\[
\text{TF}_{\text{pack}1, n} \leq \text{TS}_{\text{mix}, n+\text{Number of storage tanks}}
\]
Results: Small Example Problems

- Horizon: 48 hours

- Demand

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product 1</strong></td>
<td>40,000</td>
<td>40,000</td>
<td>32,000</td>
<td>-</td>
</tr>
<tr>
<td><strong>Product 2</strong></td>
<td>24,000</td>
<td>16,000</td>
<td>32,000</td>
<td>16,000</td>
</tr>
<tr>
<td><strong>Product 3</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16,000</td>
</tr>
<tr>
<td><strong>Product 4</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16,000</td>
</tr>
<tr>
<td><strong>Product 5</strong></td>
<td>40,000</td>
<td>40,000</td>
<td>48,000</td>
<td>-</td>
</tr>
<tr>
<td><strong>Product 6</strong></td>
<td>24,000</td>
<td>20,000</td>
<td>20,000</td>
<td>-</td>
</tr>
<tr>
<td><strong>Product 7</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40,000</td>
</tr>
<tr>
<td><strong>Product 8</strong></td>
<td></td>
<td></td>
<td></td>
<td>32,000</td>
</tr>
</tbody>
</table>
Results

- Required computational time
  - Gurobi 3.0

- RTN by Shaik and Floudas (2008)
Results

- Required computational time
  - Gurobi 3.0

Graphs showing feasibility and makespan for different cases using Gurobi 3.0.

RTN by Shaik and Floudas (2008)
Full scale example case

- Same set up: 1 mixer, 6 storage tanks, 2 packers
- 120 hour horizon
- 4 hour cleaning period every 72 hours

<table>
<thead>
<tr>
<th>Product</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand [kg]</td>
<td>80,000</td>
<td>48,000</td>
<td>32,000</td>
<td>8,000</td>
<td>112,000</td>
<td>12,000</td>
<td>48,000</td>
<td>24,000</td>
</tr>
</tbody>
</table>

- No solution within 36 hours
Heuristics

- **Bottleneck**
  - Minimum makespan 1\textsuperscript{st} packer: 118.33 hr
  - Minimum makespan 2\textsuperscript{nd} packer: 109.44 hr

- **Products on the 1\textsuperscript{st} packer in optimal order**
  - 4-3-2-1

- **Feasibility optimization**
  - 28 hours
Algorithm

- **Step 1:** Order products on bottleneck stage
- **Step 2:** Relax horizon → feasibility optimization
  - 170s, 124.19hr makespan
- **Step 3:** Fix bottleneck allocation → MS minimization
  - 358s, 118.74hr makespan
Algorithm

- Step 4: Fix 2nd half allocation → MS minimization
  - 692s, 118.33hr makespan

- For example case with algorithm
  - 528s to first feasible solution
  - 1220s to optimal solution

- No guarantee of global optimality
Conclusions

- RPM model more efficient than RTN models
  - Dedicated time periods improve efficiency
  - Indirectly modeling inventory improves efficiency

- Algorithm
  - Required for larger cases
  - Cannot guarantee global optimality
  - Gives good results within reasonable time
Future work

- Tactical Planning model
  - 1-1.5 year horizon
  - Fast moving consumer goods
    - Large number of products
    - Seasonality ➔ Weekly time periods
    - Large uncertainty in demand and supply
  - Capacity Estimation
    - How to determine maximum capacity utilization?

![Graph showing production schedules for different products and machines]