Flex-Rail Final Results Dissemination Webinar

The IMPACT-2 model for Shift2Rail

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Overview of the IMPACT-2 model of Shift2Rail

Source: www.shift2rail.org
Overview of the IMPACT-2 model of Shift2Rail

1. **Quantitative KPI model**
   - Strict focus on technological innovations
   - Consequent percentages used
   - Target is the maximum achievable improvement as a priority for the respective KPI
   - Based on generic scenarios

2. **Customer Experience**
   - Focus on Areas of Major Potential for Improvement i.e. improving attractivity of the Rail System
   - Based on feedback from customers

3. **Mode-Choice model**
   - Focus on the increased use of the Rail System
   - Based on real Scenarios
Relation of the IMPACT-2 model of Shift2Rail

- **CUSTOMER EXPERIENCE**
  - Remove barriers for passengers
  - IP4 « IT solutions »

- **MODAL SHIFT**
  - KPI Reliability
  - KPI Capacity
  - KPI Life-Cycle Cost

- **SUSTAINABLE**
  - IP1 « Rolling stock »
  - IP2 « CCS »
  - IP3 « Infrastructure »
### Internal structure of the KPI model

#### Selection of SPD

- **Use cases selection**
- **Accuracy Level Minimum**

#### Overall results

- **SPD1**

#### Results w.r.t. to the IP part of the overall baseline

<table>
<thead>
<tr>
<th>Results</th>
<th>for all IPs</th>
<th>for IP1</th>
<th>for IP2</th>
<th>for IP3</th>
<th>for IPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCC</td>
<td>-21.5%</td>
<td>-1.91%</td>
<td>-1.45%</td>
<td>-8.1%</td>
<td></td>
</tr>
<tr>
<td>Punctuality</td>
<td>35.0%</td>
<td>7.0%</td>
<td>3.15%</td>
<td>18.8%</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>67.5%</td>
<td>20.85%</td>
<td>38.0%</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>LCC</td>
<td>-3.76%</td>
<td>-14.9%</td>
<td>-20.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punctuality</td>
<td>13.40%</td>
<td>23.4%</td>
<td>55.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>20.85%</td>
<td>38.0%</td>
<td>0.4%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Results w.r.t. to the IP-specific part of the baseline

- **Reference to IP baseline**

### Source

Source: www.pixabay.com

**SPD1:** High Speed  
**SPD2:** Regional  
**SPD3:** Metro  
**SPD4:** Freight
KPI-Input for Mode choice model

**Customer Experience**
- Information
- Booking & Ticketing
- Comfort & Service
Remove barriers for passengers
IP4 « IT solutions »

**Modal Shift**

**Sustainable**
- Train (load) capacity
- Maximum usable (track) capacity
- Operational cost
- Track cost

**KPIs**
- Average delay minute per train
- KPI Reliability
- KPI Capacity
- KPI Life-Cycle Cost

**IMPACT-2**
IMPACT-2 Mode choice modelling and results
Passenger mode choice models are based on theory of discrete choice

- Predefined set of alternatives: e.g. air, car, bus, rail
- Preference of an alternative quantified in the utility function:

\[
U_{\text{rail}} = V_{\text{rail}} + \varepsilon_{\text{rail}} \\
= \text{ASC}_{\text{rail}} + \beta_{\text{rail}} \ln \text{VehicleTime}_{\text{rail}} + \gamma_{\text{rail}} \text{TravelCost}_{\text{rail}} + \cdots + \varepsilon_{\text{rail}}
\]

\[
U_{\text{car}} = V_{\text{car}} + \varepsilon_{\text{car}} \\
= \text{ASC}_{\text{car}} + \beta_{\text{car}} \text{TravelTime}_{\text{car}} + \gamma_{\text{car}} \text{TravelCost}_{\text{car}} + \cdots + \varepsilon_{\text{car}}
\]

... 

- Assuming \( \varepsilon \) follows Gumbel distribution \( \rightarrow \) Multinomial Logit model

\[
P_{\text{car}} = \frac{e^{V_{\text{car}}}}{e^{V_{\text{car}}} + e^{V_{\text{bus}}} + e^{V_{\text{rail}}} + e^{V_{\text{air}}}}
\]
Assumptions

• Only the end situation when all Shift2Rail innovations are realized is modelled – not the implementation path
• Changes in population development, income etc. are not considered – the innovations are applied to today’s situation to isolate the effects of innovations
• Only one corridor per SPD is considered
• Only demand in the peak hour is modelled
• Only one type of traveller is considered: an “average” traveller
• Total number of travellers (for all modes) is assumed to be constant
• Congestion on the road network is not taken into account
Baseline mode choice models

• To build the baseline mode choice models, we need:

  • Baseline demand
  • Service attributes: travel time, travel cost, average delay, customer experience variables (Booking & ticketing, information, comfort) etc.
  • Passenger valuations: value of time (Swedish, French and EEU Value of time sets), value of customer experience
Supply constraints

• There exists supply constraints
  • Number of trains per hour is limited by the maximum usable track capacity
  • Number of passengers per train is limited by train seat capacity
  • Negative effects of crowding are captured by a discomfort factor (based on the load factor)
We assume operators will only adjust ticket cost and frequency:

- High-speed: operators maximize profit both in baseline and in future scenarios
- Regional and metro: Producer surplus is kept as in baseline and profit above that is used to decrease ticket prices and/or increase frequency
**SPD High-speed passenger rail**

Important characteristics of the studied corridor

- Busy corridor in a high-density area
- Maximum usable track capacity reached already in baseline (12 trains/h)
- Large share of long-distance rail already in baseline (24%)
- Average delay small compared to corridor travel time
- Main competing mode is private car
Improvements in S2R impact scenario – High-speed

- Maximum usable track capacity increases substantially → important for operator’s decision regarding train frequency (running at full capacity in baseline)
- Full deployment of high-speed S2R customer experience improvements assumed (100%)
- Substantial reduction of average delay minutes (-35%) but delay minutes are small compared to in-vehicle travel time for the corridor

<table>
<thead>
<tr>
<th>Input data item</th>
<th>Unit</th>
<th>Percentage difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average delay minute per train</td>
<td>min</td>
<td>-35%</td>
</tr>
<tr>
<td>Train capacity</td>
<td>seats/ train</td>
<td>+11%</td>
</tr>
<tr>
<td>Maximum usable track capacity</td>
<td>trains/h</td>
<td>+33%</td>
</tr>
<tr>
<td>Operational cost</td>
<td>€/train</td>
<td>-6%</td>
</tr>
<tr>
<td>Track cost</td>
<td>€/train</td>
<td>-16%</td>
</tr>
<tr>
<td>Customer experience variables</td>
<td>Normalized to 1</td>
<td>+100%</td>
</tr>
</tbody>
</table>
Results: High speed

- Modal share
  - Significant effect of S2R innovations (rail modal share increases from 24% to 35%)
  - S2R scenario rail modal share does not depend on the value of time (VOT) assumptions
High speed – Which factors contribute the most?

- **Frequency** in S2R impact scenario has reached improved maximum usable track capacity, which is the main driver (reduction of waiting time)
- **Customer experience improvements** have substantial effects, but they are constrained by the maximum usable track capacity
- Modest effects of delay reduction and reduced operational and track costs
Alternative future scenarios for AV and EV innovation

- Moderate and optimistic Automated vehicles (AVs) scenarios
- Moderate and optimistic Electric vehicles (EVs) scenarios
- Assumptions on market share and changes in value of time and travel cost from literature review
- Only minor changes in assumptions between high-speed, regional and metro

<table>
<thead>
<tr>
<th>Data item</th>
<th>Source</th>
<th>Adopted values</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger valuations of peak hour average in-vehicle travel time for AVs</td>
<td>Kolarova et al. (2018) [19]; Correia et al. (2019) [20]</td>
<td>Moderate 86% and Optimistic 73%</td>
</tr>
<tr>
<td>Passenger valuations of peak hour average access and egress travel time for bus</td>
<td>Kolarova et al. (2018) [19]</td>
<td>Moderate 84% and Optimistic 67%</td>
</tr>
<tr>
<td>Peak hour average access and egress travel time for bus</td>
<td>Near2050 D5.3 (2018) [18]; CoExist D4.2 (2020) [29]</td>
<td>Moderate 100.5% and Optimistic 97%</td>
</tr>
<tr>
<td>Peak hour average in-vehicle travel time for AVs</td>
<td>Milakis et al. (2017) [22]; Near2050 D5.3 (2018) [18]; CoExist D4.2 (2020) [29]</td>
<td>Moderate 100.5% and Optimistic 97%</td>
</tr>
<tr>
<td>Peak hour average travel cost for AVs</td>
<td>Milakis et al. (2017) [22]; Near2050 D5.3 (2018) [18]; Fagnant, et al. (2015) [24]</td>
<td>Moderate 104% and Optimistic 75%</td>
</tr>
<tr>
<td>Market share of AVs</td>
<td>Milakis et al., (2017) [22]</td>
<td>Moderate 40% and Optimistic 100%</td>
</tr>
<tr>
<td>Climate innovation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak hour average travel cost for EVs</td>
<td>Jensen et al. (2017) [26]; Bösch et al., (2018) [25]; Lutsey and Nicholas (2019) [27]</td>
<td>Moderate 40% and Optimistic 70%</td>
</tr>
<tr>
<td>Market share of EVs</td>
<td>Liu et al. (2017) [15]</td>
<td>Moderate 50% and Optimistic 100%</td>
</tr>
</tbody>
</table>
AV and EV scenario results – High-speed

- Shift2Rail innovations are also present, results for Swedish value of time set
- Moderate AV and EV innovation do not affect rail demand but lower ticket prices
- Optimistic EV innovation wipe out the rail demand increase of S2R

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Rail mode share (%)</th>
<th>Ticket price (€)</th>
<th>Frequency</th>
<th>Load factor</th>
<th>Producer surplus (€)</th>
<th>Consumer surplus (€)</th>
</tr>
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<tbody>
<tr>
<td>Baseline</td>
<td>24%</td>
<td>47</td>
<td>12</td>
<td>0.80</td>
<td>176760</td>
<td>0</td>
</tr>
<tr>
<td>Shift2Rail</td>
<td>35%</td>
<td>63</td>
<td>16</td>
<td>0.80</td>
<td>393771</td>
<td>31438</td>
</tr>
<tr>
<td></td>
<td>(48%)</td>
<td>(34%)</td>
<td>(33%)</td>
<td>(0%)</td>
<td>(123%)</td>
<td>/</td>
</tr>
<tr>
<td>Moderate AV</td>
<td>35%</td>
<td>59</td>
<td>16</td>
<td>0.80</td>
<td>365955</td>
<td>(107%)</td>
</tr>
<tr>
<td></td>
<td>(48%)</td>
<td>(26%)</td>
<td>(33%)</td>
<td>(0%)</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Moderate EV</td>
<td>35%</td>
<td>43</td>
<td>16</td>
<td>0.80</td>
<td>251006</td>
<td>440542</td>
</tr>
<tr>
<td></td>
<td>(48%)</td>
<td>(-8%)</td>
<td>(33%)</td>
<td>(0%)</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Optimistic AV</td>
<td>29%</td>
<td>27</td>
<td>16</td>
<td>0.66</td>
<td>97432</td>
<td>881578</td>
</tr>
<tr>
<td></td>
<td>(23%)</td>
<td>(-43%)</td>
<td>(33%)</td>
<td>(-17%)</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Optimistic EV</td>
<td>17%</td>
<td>23</td>
<td>11</td>
<td>0.58</td>
<td>37906</td>
<td>1099185</td>
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<td></td>
<td>(-27%)</td>
<td>(-52%)</td>
<td>(-8%)</td>
<td>(-28%)</td>
<td>/</td>
<td></td>
</tr>
</tbody>
</table>
SPD Regional

- Similar model type as for high-speed SPD, even though the alternative modes differ
- Frequency much lower than maximum usable track capacity (capacity constrained only at some nodes)
- Average delay minutes decreases substantially (-52%)
- Significant effect of S2R innovations (rail modal share increases from 18% to 29-40% depending on the value of time (VOT) assumptions)
- Already Moderate EV innovation reduce S2R rail demand increases substantially
- Optimistic AV and EV innovation wipe out the S2R rail demand increases
**SPD Metro**

- Similar model type as for high-speed SPD, even though the alternative modes differ
- Frequency at maximum usable track capacity and is not increased by S2R innovations
- Only minor effects of S2R innovations (rail modal share increases from 30% to 31%)
- Inelastic SPD – Small demand changes also in Optimistic AV and EV scenarios
SPD Freight - Modelling

• KPI computations based on a generic corridor
• Modal share computations are done over an entire network (Sweden).
• Network model: Samgods (cost-minimizing model)
• We represent improvements in terms of percentages.
• Evaluation: Tonnes-km on Swedish territory only (and territorial waters). Reason for this is that flows over the Baltic Sea may cause untypical results for European conditions.
SPD Freight – Results

- Very strong impact on modal shift by S2R innovations (rail modal share increases from 21% to 32-47% depending on capacity constraints on rail or not)
- However, large variations for different commodity types.
- Most important drivers are (probably): reduced operational costs, driving time and max load capacity.
- Assumptions that S2R improvements are done on the whole rail network may be too optimistic (?)
- No improvements on sea have been considered.
Back up
Modelling Approach for the KPI scenarios

Baseline scenario

Future scenario

Shift2Rail innovations

Data input from the IPs

Reference scenario:

- SPD1: High Speed
- SPD2: Regional
- SPD3: Metro
- SPD4: Freight

Source: www.shift2rail.org

Source: www.pixabay.com
Modelling Approach per KPI

1. LCC model
   • Capital and Maintenance cost of IP1, IP2, IP3, IP5 and Operational
   • IP-wise sum of cost share of TD in baseline in % and improvement by S2R innovations %

2. Capacity model
   • Capacity calculation consist of three main parts:
     • Track Capacity (number of trains per peak hour / day)
     • Train Capacity (passenger / metric ton per train)
     • Coupling ability (coupled units per train)
   • For Passenger SPDs: Passengers in Peak Hour
   • For Freight SPD: Freight in 24h

3. Punctuality model
   • Failure rates linked to delay minutes based on historic data
   • Reduction of Delay Sources in % by S2R Innovations
KPI-Input for Mode choice model

**KPI model**
- LCC model
- Punctuality model
- Capacity model

**Mode choice model**
- Operational cost
- Track cost
- Average delay minute per train
- Train capacity / Train load capacity
- Maximum usable capacity / maximum usable track capacity
KPI-Input for Mode choice model

Source: www.shift2rail.org
### S2R Customer Experience Variables

<table>
<thead>
<tr>
<th>Booking and ticketing</th>
<th>Information</th>
<th>Comfort &amp; services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personalized booking</td>
<td>Real-time information</td>
<td>Train layout</td>
</tr>
<tr>
<td>Integrated ticket system</td>
<td>Travel assistant</td>
<td>Train noise</td>
</tr>
<tr>
<td>Multimodal shopping</td>
<td>Information on ancillary services</td>
<td>Station design</td>
</tr>
<tr>
<td>Simple ticket(s) purchase</td>
<td>Navigation pre/during trip</td>
<td>Station services</td>
</tr>
<tr>
<td>Offer adapted to my need</td>
<td>Support in disruption</td>
<td>AMPIs related to IP1 &amp; IP3</td>
</tr>
</tbody>
</table>

AMPIs related to IP4
Improvements in S2R impact scenario – Regional

- Average delay minutes decreases substantially (-52%)
- Large increase in maximum usable track capacity but has no effect
- Full deployment of regional S2R customer experience improvements assumed (100%)

<table>
<thead>
<tr>
<th>Input data item</th>
<th>Unit</th>
<th>Baseline value</th>
<th>S2R impact scenario</th>
<th>Percentage difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average delay minute per train</td>
<td>Min</td>
<td>6.9</td>
<td>3.3</td>
<td>-52%</td>
</tr>
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<td>Train capacity</td>
<td>seats/train</td>
<td>220</td>
<td>248</td>
<td>+13%</td>
</tr>
<tr>
<td>Maximum usable track capacity</td>
<td>trains/h</td>
<td>14</td>
<td>20</td>
<td>+36%</td>
</tr>
<tr>
<td>Operational cost</td>
<td>€/train</td>
<td>444</td>
<td>377</td>
<td>-15%</td>
</tr>
<tr>
<td>Track cost</td>
<td>€/train</td>
<td>600</td>
<td>485</td>
<td>-20%</td>
</tr>
<tr>
<td>Customer experience variables</td>
<td>Normalized to 1</td>
<td>1</td>
<td>2</td>
<td>+100%</td>
</tr>
</tbody>
</table>
**Results: Regional**

- **Modal share**
  - Significant effect of S2R innovations (rail modal share increases from 18% to 29-40%)
  - S2R scenario rail modal share depend a lot on the value of time (VOT) assumptions
Regional – Which factors contribute the most?

- The main drivers of increased rail demand for French and Swedish VOT are **frequency increase** (reduction of waiting time) and **delay reduction**.
- The main drivers of increased rail demand for EEU VOT are **customer experience innovations** (but this is to some extent an artefact of the model).
- Modest effects of increased train capacity and reduced operational and track costs.

![Individual S2R innovation effects on rail demand increase (%)](chart.png)
AV and EV scenario results – Regional

- Shift2Rail innovations are also present, results for Swedish value of time set
- Already Moderate EV innovation reduce S2R rail demand increases substantially
- Optimistic AV and EV innovation wipe out the S2R rail demand increases

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Rail mode share (%)</th>
<th>Ticket price (€)</th>
<th>Frequency</th>
<th>Load factor</th>
<th>Producer surplus (€)</th>
<th>Consumer surplus (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>18%</td>
<td>6.9</td>
<td>2</td>
<td>1.83</td>
<td>3225</td>
<td>0</td>
</tr>
<tr>
<td>Shift2Rail</td>
<td>37%</td>
<td>6.6</td>
<td>3</td>
<td>2.09</td>
<td>7613</td>
<td>10343</td>
</tr>
<tr>
<td>(102%)</td>
<td>(-5%)</td>
<td>(50%)</td>
<td>(14%)</td>
<td>(136%)</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Moderate AV</td>
<td>28%</td>
<td>6.4</td>
<td>2</td>
<td>2.41</td>
<td>5986</td>
<td>10926</td>
</tr>
<tr>
<td>(55%)</td>
<td>(-7%)</td>
<td>(0%)</td>
<td>(32%)</td>
<td>(86%)</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Moderate EV</td>
<td>23%</td>
<td>6.3</td>
<td>2</td>
<td>1.92</td>
<td>4269</td>
<td>27282</td>
</tr>
<tr>
<td>(24%)</td>
<td>(-9%)</td>
<td>(0%)</td>
<td>(5%)</td>
<td>(32%)</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Optimistic AV</td>
<td>14%</td>
<td>5.8</td>
<td>2</td>
<td>1.23</td>
<td>1817</td>
<td>55994</td>
</tr>
<tr>
<td>(-21%)</td>
<td>(-16%)</td>
<td>(0%)</td>
<td>(-33%)</td>
<td>(-44%)</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Optimistic EV</td>
<td>12%</td>
<td>5.5</td>
<td>2</td>
<td>1.03</td>
<td>1078</td>
<td>67077</td>
</tr>
<tr>
<td>(-34%)</td>
<td>(-20%)</td>
<td>(0%)</td>
<td>(-44%)</td>
<td>(-67%)</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>
Improvements in S2R impact scenario – Metro

- Minor improvements in train capacity
- No improvement of maximum usable track capacity which is an important constraints for this metro corridor
- Full deployment of metro customer experience (CE) improvements assumed (100%), but low valuations of CE improvements for metro

<table>
<thead>
<tr>
<th>Input data item</th>
<th>Unit</th>
<th>Baseline value</th>
<th>S2R impact scenario</th>
<th>Percentage difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train capacity</td>
<td>seats/train</td>
<td>900</td>
<td>916</td>
<td>2%</td>
</tr>
<tr>
<td>Maximum usable track capacity</td>
<td>trains/h</td>
<td>24</td>
<td>24</td>
<td>+/-0%</td>
</tr>
<tr>
<td>Operational cost</td>
<td>€/train</td>
<td>83</td>
<td>70</td>
<td>-16%</td>
</tr>
<tr>
<td>Track cost</td>
<td>€/train</td>
<td>60</td>
<td>54</td>
<td>-10%</td>
</tr>
<tr>
<td>Customer experience variables</td>
<td>Normalized to 1</td>
<td>1</td>
<td>2</td>
<td>+100 %</td>
</tr>
</tbody>
</table>
Results: Metro

- Modal share
  - Minor effect of S2R innovations (rail modal share increases from 30% to 31%)
  - S2R rail modal share does not depend on the value of time (VOT) assumptions
Metro – Which factors contribute the most?

- Only small rail demand increases across the different factors
- Customer experience variables show somewhat larger effects than the other innovations
AV and EV scenario results – Metro

- Shift2Rail innovations are also present, results for Swedish value of time set
- Inelastic SPD – Small demand changes also in Optimistic AV and EV scenarios

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Rail mode share (%)</th>
<th>Ticket price (€)</th>
<th>Frequency</th>
<th>Load factor</th>
<th>Producer surplus (€)</th>
<th>Consumer surplus (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>30.3%</td>
<td>1.68</td>
<td>24</td>
<td>0.85</td>
<td>27413</td>
<td>0</td>
</tr>
<tr>
<td>Shift2Rail</td>
<td>31.2%</td>
<td>1.65</td>
<td>24</td>
<td>0.86</td>
<td>28314</td>
<td>4450</td>
</tr>
<tr>
<td>Moderate AV</td>
<td>31.1%</td>
<td>1.65</td>
<td>24</td>
<td>0.86</td>
<td>28133</td>
<td>7778</td>
</tr>
<tr>
<td>Moderate EV</td>
<td>30.6%</td>
<td>1.65</td>
<td>24</td>
<td>0.84</td>
<td>27700</td>
<td>15869</td>
</tr>
<tr>
<td>Optimistic AV</td>
<td>29.2%</td>
<td>1.65</td>
<td>24</td>
<td>0.81</td>
<td>26283</td>
<td>43079</td>
</tr>
<tr>
<td>Optimistic EV</td>
<td>29.6%</td>
<td>1.65</td>
<td>24</td>
<td>0.82</td>
<td>26629</td>
<td>36318</td>
</tr>
</tbody>
</table>
Samgods: capacity constraints on rail

- Computed train flows will exceed realistic limits (capacities) on some rail links unless restricted.
- A special module has been developed in Samgods to redirect exceeding flows so that the capacity limits (# trains per day) are not exceeded.
- Capacity limits have been estimated by the Swedish Transport Administration.
- This module has significantly increased the computational complexity of the model.
Samgods: cost minimizing model

• Starting point: transport demand (160 PC matrices)

• Data originates from a commodity flow survey + import/export statistics.

• End result: flows on a network

• Plus everything that can be derived from the flows: tonne-kms, veh-kms, costs, load factors etc.
## Improvements in S2R impact scenario – Freight

**"KPI innovations"**

<table>
<thead>
<tr>
<th>Input data item</th>
<th>Unit</th>
<th>Single wagon trains</th>
<th>Block trains</th>
<th>Combi trains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average delay</td>
<td>min/train</td>
<td>-59%</td>
<td>-59%</td>
<td>-59%</td>
</tr>
<tr>
<td>Max load capacity</td>
<td>tonnes/train</td>
<td>+20%</td>
<td>+50%</td>
<td>+70%</td>
</tr>
<tr>
<td>Track capacity</td>
<td>trains/day</td>
<td>+5%</td>
<td>+5%</td>
<td>+5%</td>
</tr>
<tr>
<td>Operational cost</td>
<td>€/km</td>
<td>-10%</td>
<td>+20%</td>
<td>+70%</td>
</tr>
<tr>
<td>(energy)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational cost</td>
<td>€/h</td>
<td>-20%</td>
<td>-10%</td>
<td>0%</td>
</tr>
<tr>
<td>(loco+wagon+labor)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track costs</td>
<td>€/km</td>
<td>-19%</td>
<td>-19%</td>
<td>-19%</td>
</tr>
</tbody>
</table>

**"Time reductions"**

<table>
<thead>
<tr>
<th>Process time type</th>
<th>Unit</th>
<th>Single wagon trains</th>
<th>Block trains</th>
<th>Combi trains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading/Unloading</td>
<td>h</td>
<td>-50%</td>
<td>-50%</td>
<td>-50%</td>
</tr>
<tr>
<td>Shunting at orig&amp;dest terminals</td>
<td>h</td>
<td>-80%</td>
<td>-80%</td>
<td>-80%</td>
</tr>
<tr>
<td>Wagon&amp;brake tests</td>
<td>h</td>
<td>-80%</td>
<td>-80%</td>
<td>-80%</td>
</tr>
<tr>
<td>Marshalling</td>
<td>h</td>
<td>-20%</td>
<td>-50%</td>
<td>-50%</td>
</tr>
<tr>
<td>Driving</td>
<td>h</td>
<td>-29%</td>
<td>-33%</td>
<td>-44%</td>
</tr>
<tr>
<td>(Un/load+shunting+wagon&amp;brake tests)</td>
<td>h</td>
<td>-56%</td>
<td>-56%</td>
<td>-56%</td>
</tr>
</tbody>
</table>
Preliminary results: Freight – Modal share

- Large effects of S2R innovations (rail modal share increases from 21% to 32-47%)
- S2R scenario rail modal share depend a lot on capacity constraints assumptions
- The Samgods model has been calibrated for the “with constraints” case (so baseline results differ)