Flex-Rail Final Results Dissemination Webinar

The IMPACT-2 model for Shift2Rail

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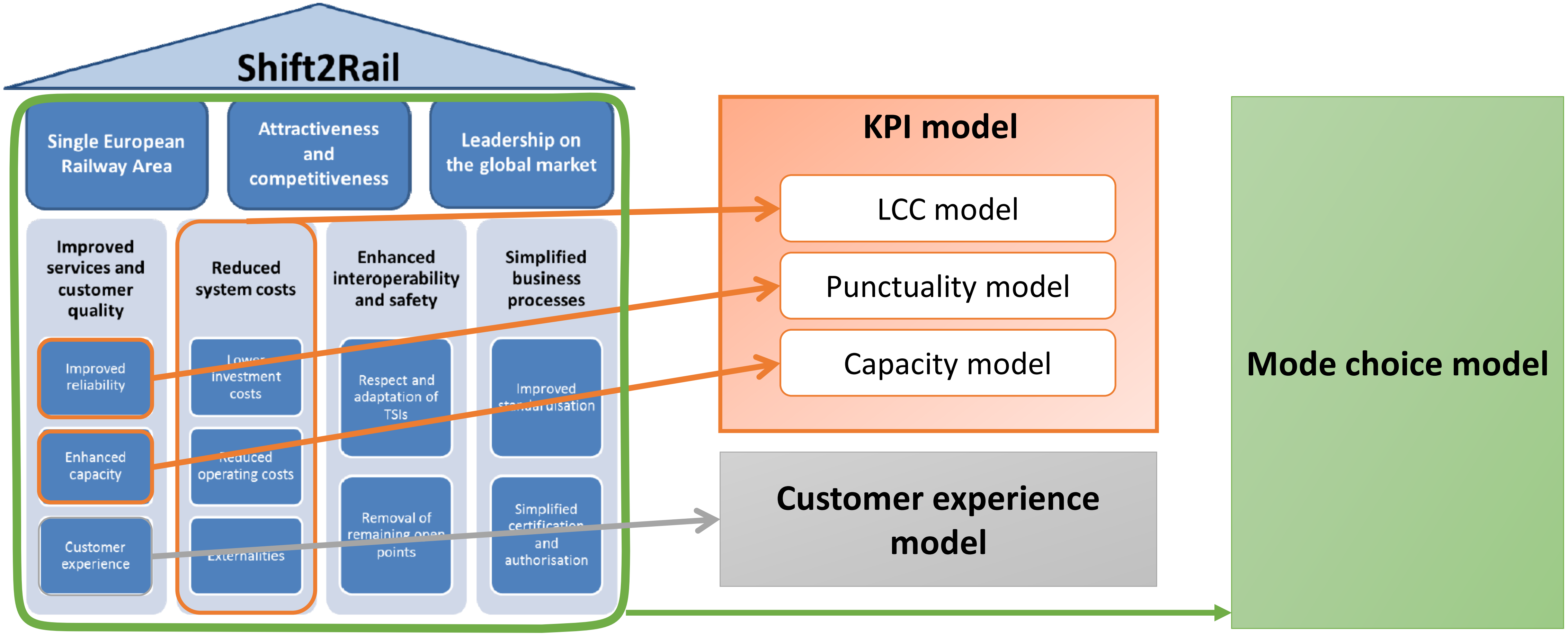
30th June 2021

Overview of the IMPACT-2 model of Shift2Rail

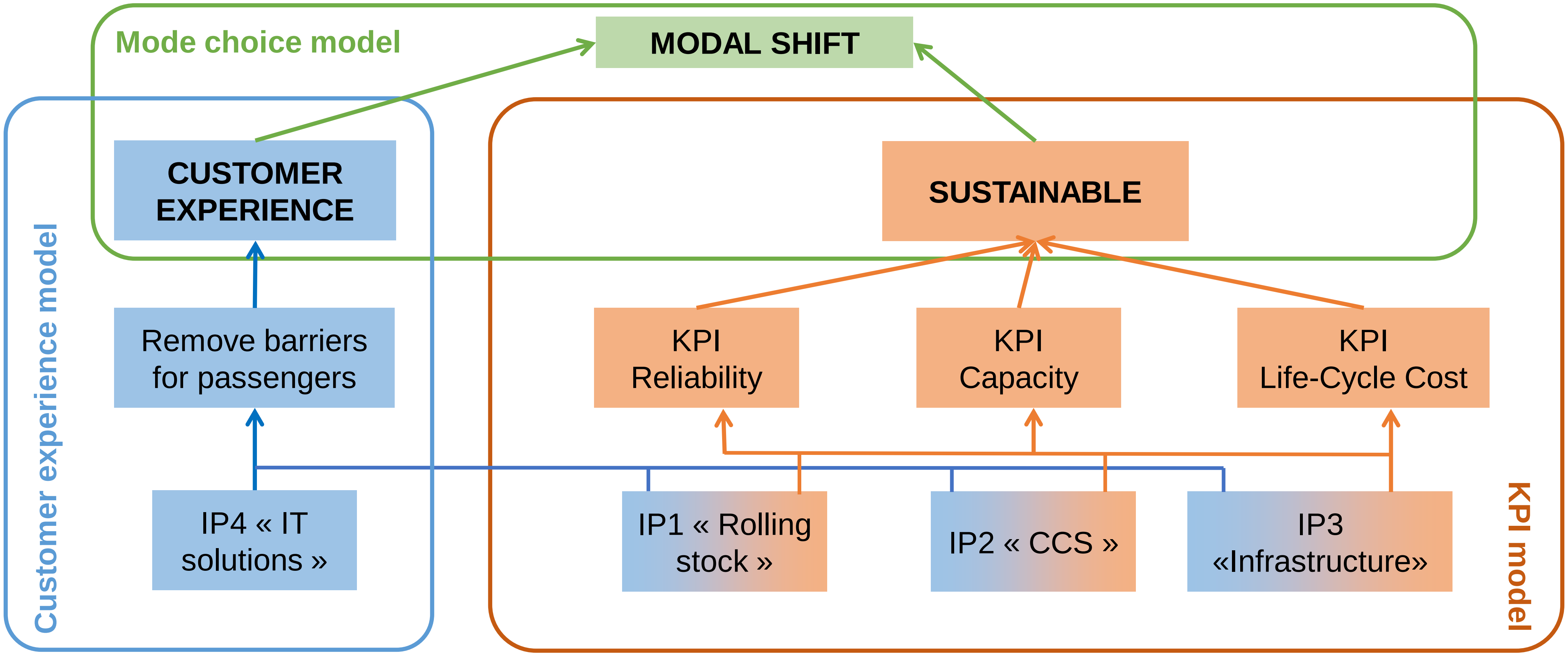


Source: www.shift2rail.org

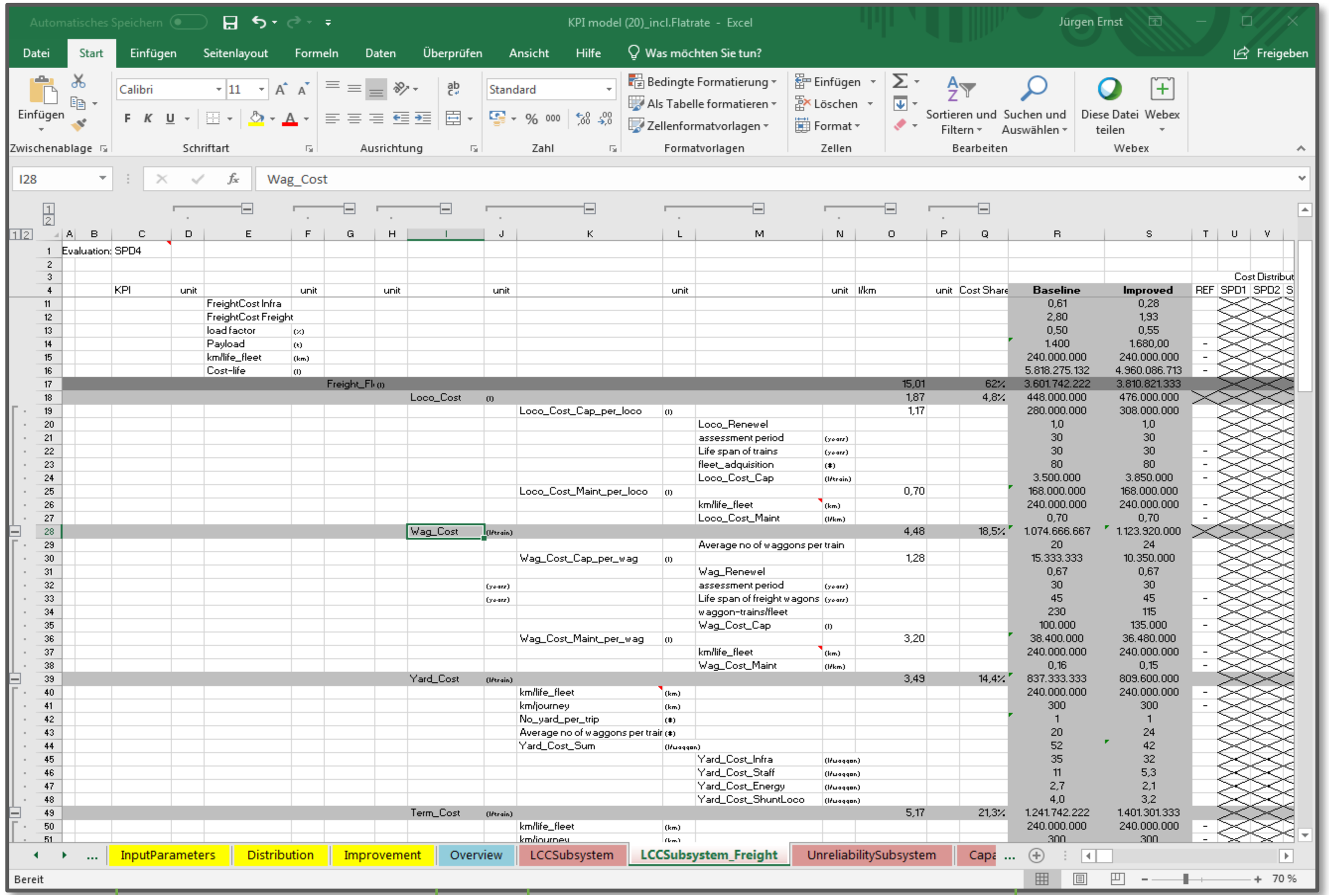
Overview of the IMPACT-2 model of Shift2Rail

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



Internal structure of the KPI model



Input parameters

Results

Models for LCC, punctuality & capacity

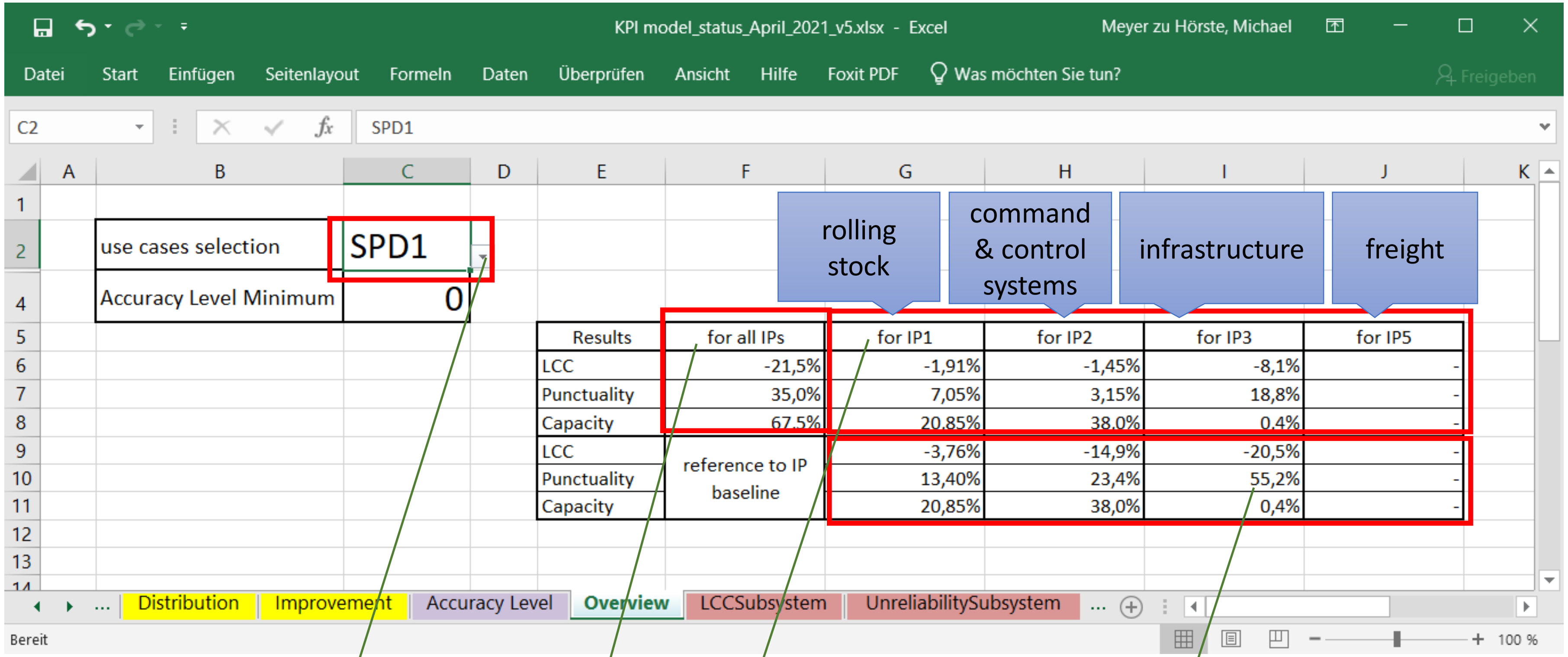
Sheet 3: InputParameters
Sheet 4: Distribution
Sheet 5: Improvements

Sheet 7: LCCSubsystem
Sheet 8: UnreliabilitySubsystem
Sheet 9: Capacity_Subsystem
Sheet 10: LCCSubsystem_Freight
Sheet 11: Unreliability_Freight
Sheet 12: Capacity_Freight

Sheet 6: Overview

Sheet 1: Cover & History
Sheet 2: SPDParameters
Sheet 13: Decisions
Sheet 14: Sources

Internal structure of the KPI model



Results	for all IPs	for IP1	for IP2	for IP3	for IP5
LCC	-21,5%	-1,91%	-1,45%	-8,1%	-
Punctuality	35,0%	7,05%	3,15%	18,8%	-
Capacity	67,5%	20,85%	38,0%	0,4%	-
LCC	reference to IP baseline	-3,76%	-14,9%	-20,5%	-
Punctuality		13,40%	23,4%	55,2%	-
Capacity		20,85%	38,0%	0,4%	-

Selection of SPD

Overall results

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

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

SPD1: High Speed

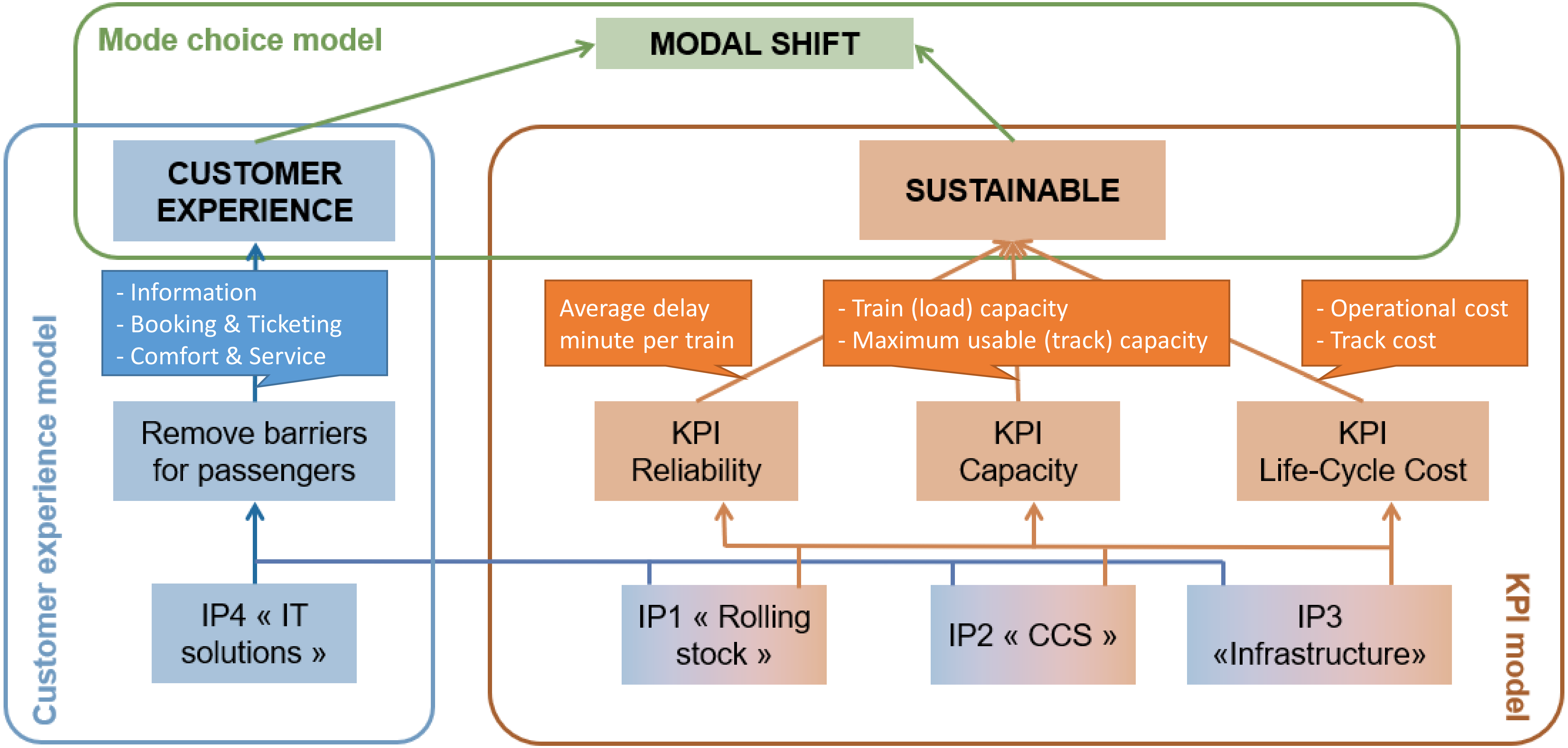
SPD2: Regional

SPD3: Metro

SPD4: Freight

Source: www.pixabay.com

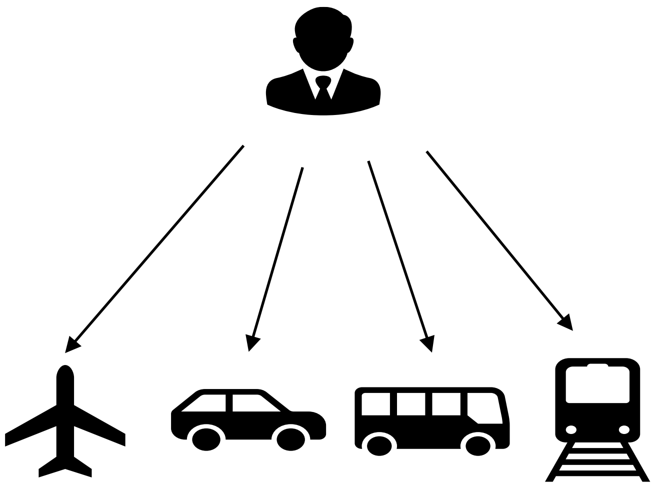
KPI-Input for Mode choice model



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:



$$U_{rail} = V_{rail} + \varepsilon_{rail}$$
$$= ASC_{rail} + \beta_{rail} InVehicleTime_{rail} + \gamma_{rail} TravelCost_{rail} + \cdots + \varepsilon_{rail}$$

$$U_{car} = V_{car} + \varepsilon_{car}$$
$$= ASC_{car} + \beta_{car} TravelTime_{car} + \gamma_{car} TravelCost_{car} + \cdots + \varepsilon_{car}$$

…

- Assuming ε follows Gumbel distribution → Multinomial Logit model

$$P_{car} = \frac{e^{V_{car}}}{e^{V_{car}} + e^{V_{bus}} + e^{V_{rail}} + e^{V_{air}}}$$

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

Source: www.pixabay.com

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)

Optimisation

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

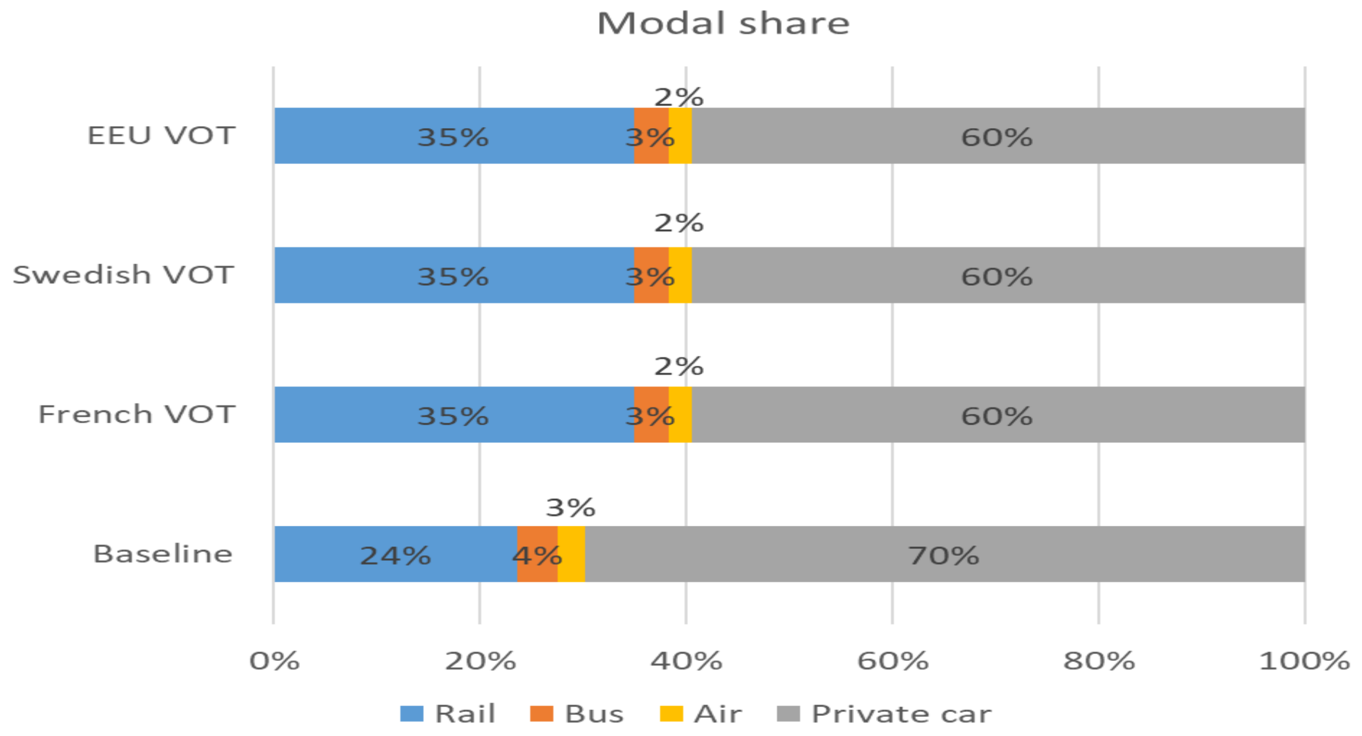
Improvements in S2R impact scenario – High-speed

- 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

Input data item	Unit	Percentage difference
Average delay minute per train	min	-35%
Train capacity	seats/train	+11%
Maximum usable track capacity	trains/h	+33%
Operational cost	€/train	-6%
Track cost	€/train	-16%
Customer experience variables	Normalized to 1	+100 %

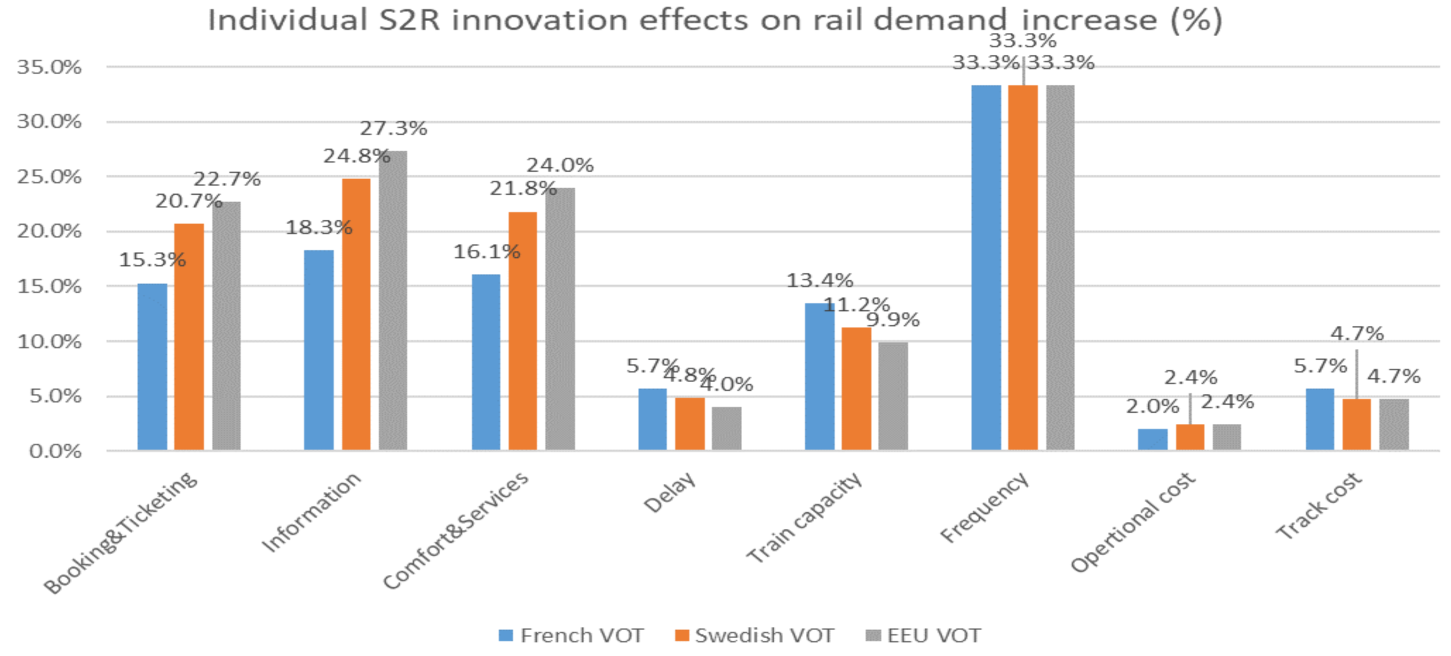
Results: High speed

- 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

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

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

Scenario name	Rail mode share (%)	Ticket price (€)	Frequency	Load factor	Producer surplus (€)	Consumer surplus (€)
Baseline	24%	47	12	0.80	176760	0
Shift2Rail	35%	63	16	0.80	393771	31438
	(48%)	(34%)	(33%)	(0%)	(123%)	/
Moderate AV	35%	59	16	0.80	365955	111147
	(48%)	(26%)	(33%)	(0%)	(107%)	/
Moderate EV	35%	43	16	0.80	251006	440542
	(48%)	(-8%)	(33%)	(0%)	(42%)	/
Optimistic AV	29%	27	16	0.66	97432	881578
	(23%)	(-43%)	(33%)	(-17%)	(-45%)	/
Optimistic EV	17%	23	11	0.58	37906	1099185
	(-27%)	(-52%)	(-8%)	(-28%)	(-79%)	/

SPD Regional

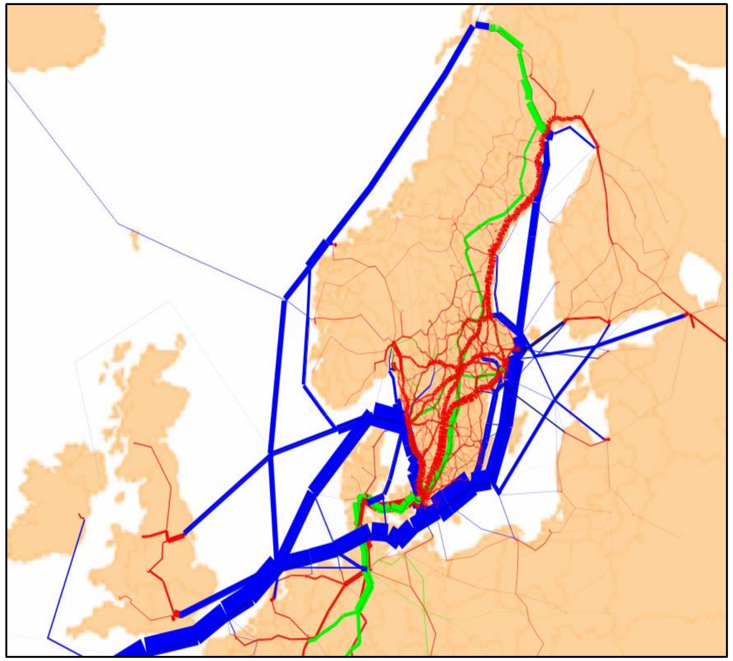
- Similar model type as for high-speed SPD, even though the alternative modes differ
- Frequency much lower than maximum usable track capacity (capacity constrained only at some nodes)
- Average delay minutes decreases substantially (-52%)
- Significant effect of S2R innovations (rail modal share increases 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.



IMPACT-2

SPD Freight – Results

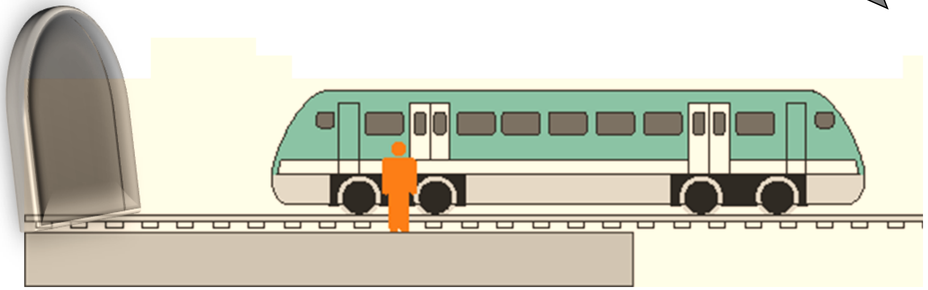
- Very strong impact on modal shift by S2R innovations (rail modal share increases from 21% to 32-47% depending on capacity constraints on rail or not)
- However, large variations for different commodity types.
- Most important drivers are (probably): reduced operational costs, driving time and max load 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

Data input from the IPs

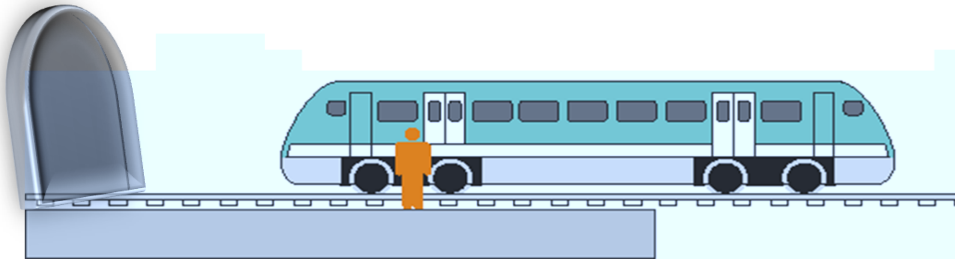
Baseline scenario



Source: www.shift2rail.org

Shift2Rail innovations

Future scenario



Reference scenario:

SPD1: High Speed

SPD2: Regional

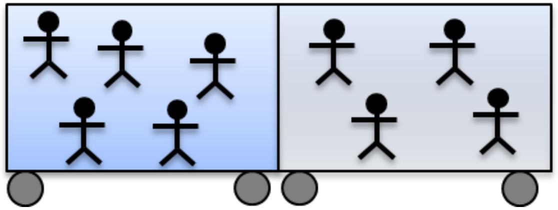
SPD3: Metro

SPD4: Freight

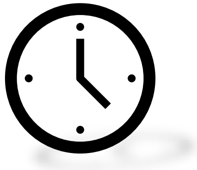
Source: www.pixabay.com

Modelling Approach per KPI

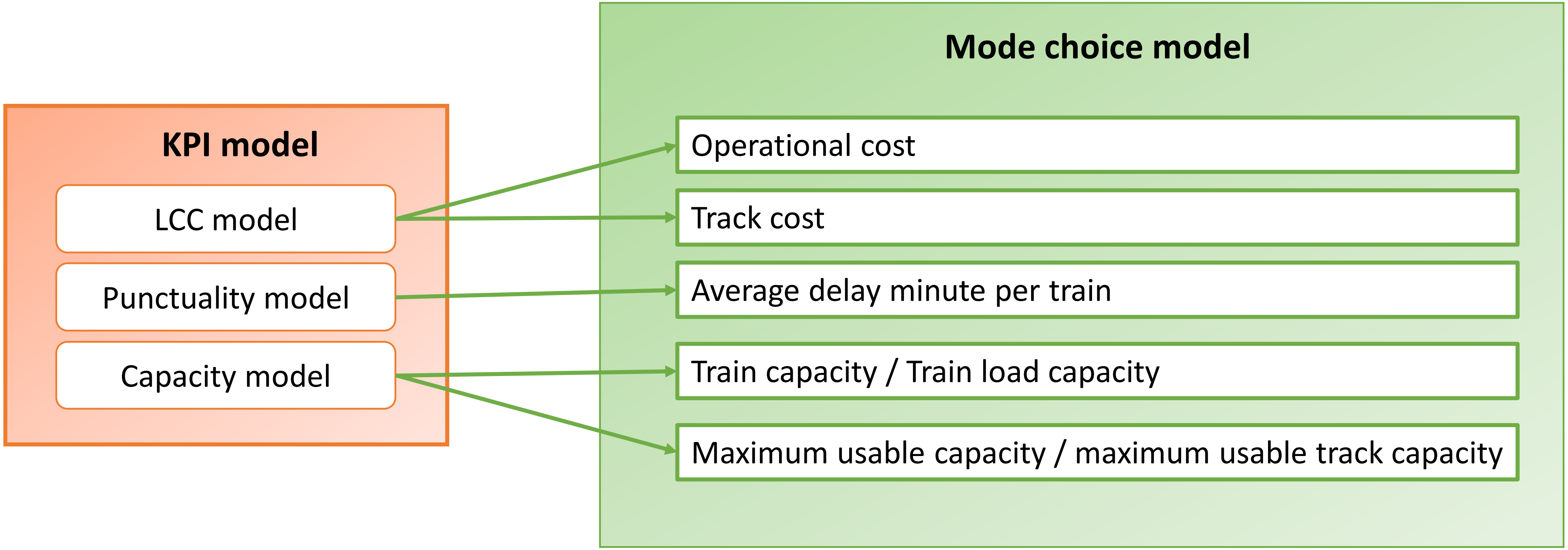
1. **LCC model**
   - Capital and Maintenance cost of IP1, IP2, IP3, IP5 and Operational
   - IP-wise sum of cost share of TD in baseline in % and improvement by S2R innovations %
2. **Capacity model**
   - Capacity calculation consist of three main parts:
     - Track Capacity (number of trains per 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



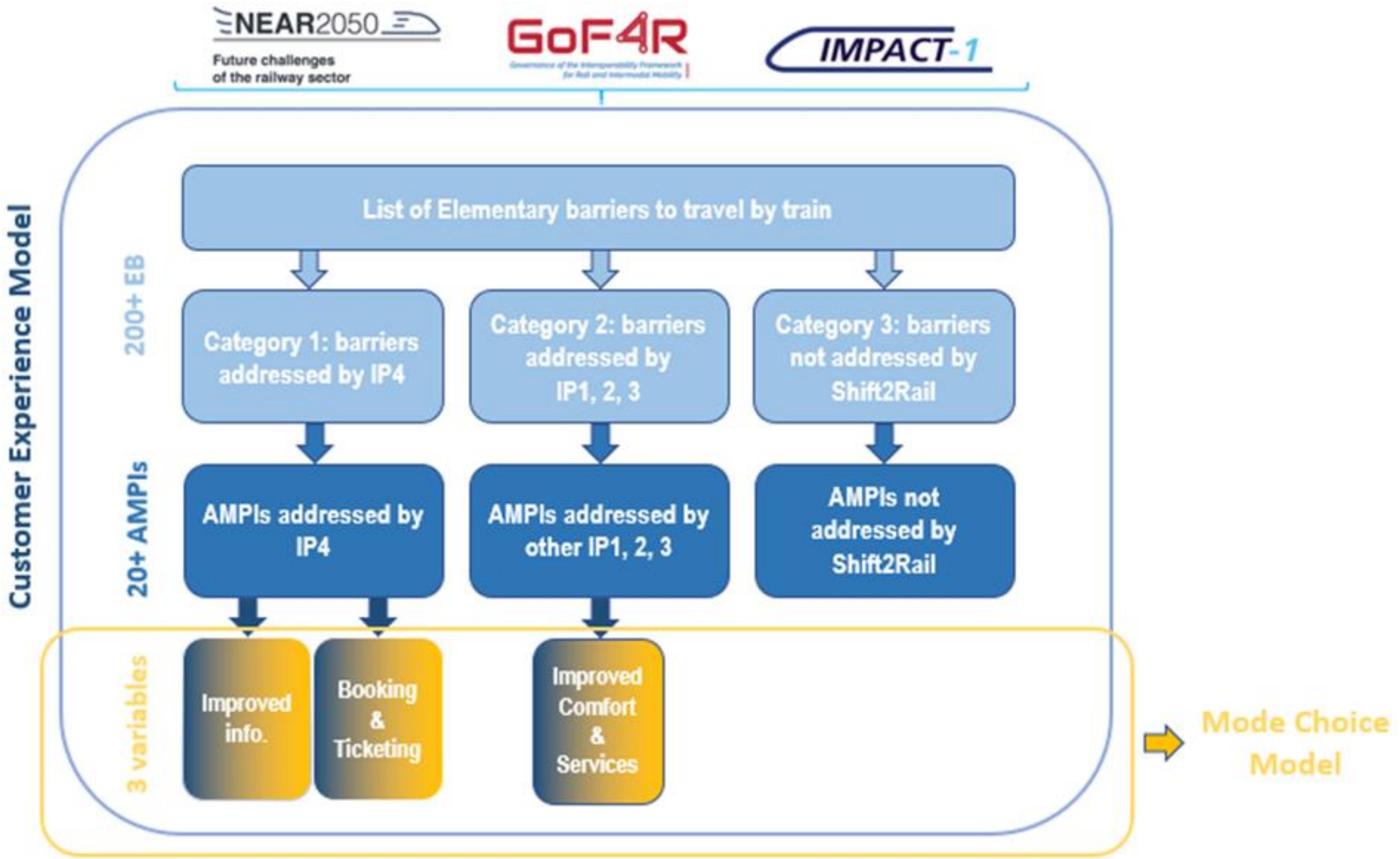
3. **Punctuality model**
   - Failure rates linked to delay minutes based on historic data
   - Reduction of Delay Sources in % by S2R Innovations



KPI-Input for Mode choice model



KPI-Input for Mode choice model



Source: www.shift2rail.org

S2R Customer Experience Variables

Booking and ticketing	Information	Comfort & services
Personalized booking	Real-time information	Train layout
Integrated ticket system	Travel assistant	Train noise
Multimodal shopping	Information on ancillary services	Station design
Simple ticket(s) purchase	Navigation pre/during trip	Station services
Offer adapted to my need	Support in disruption	

AMPIs related to IP4

AMPIs related to IP1 & IP3

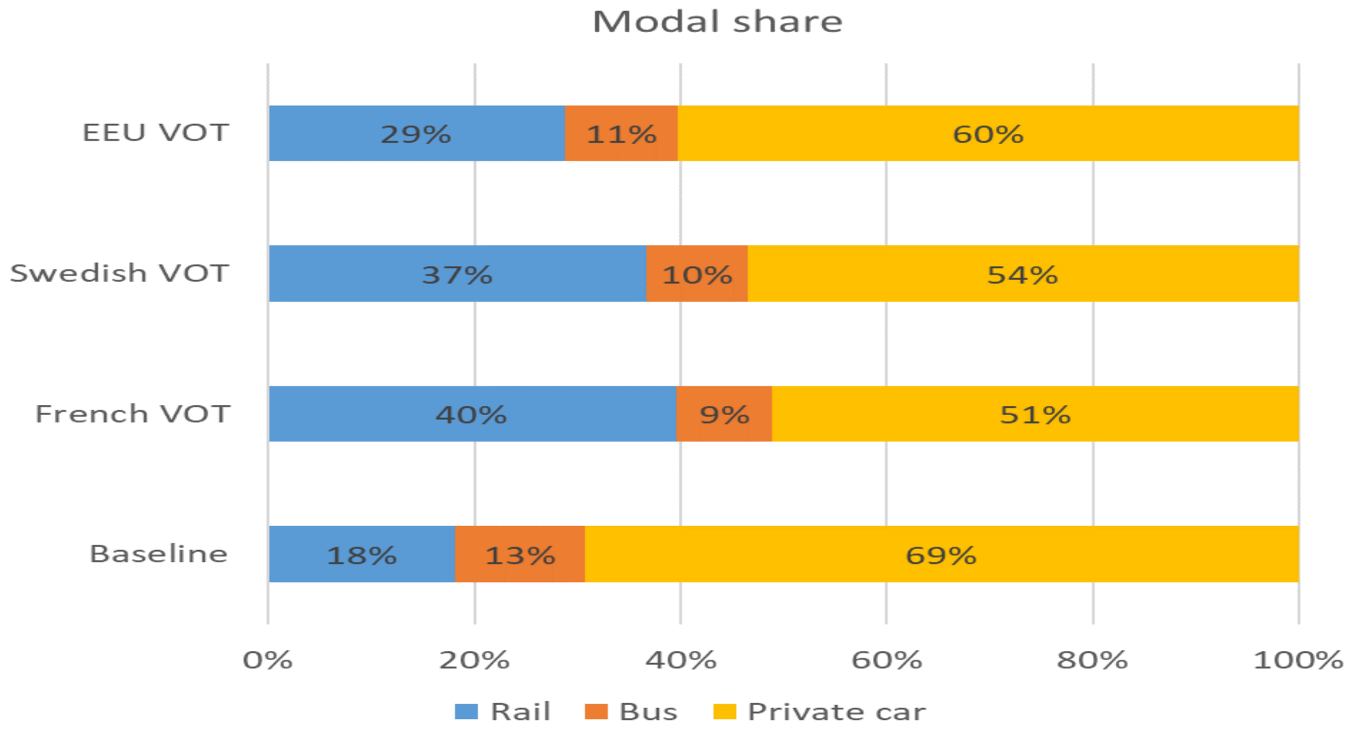
Improvements in S2R impact scenario – Regional

- 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%)

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

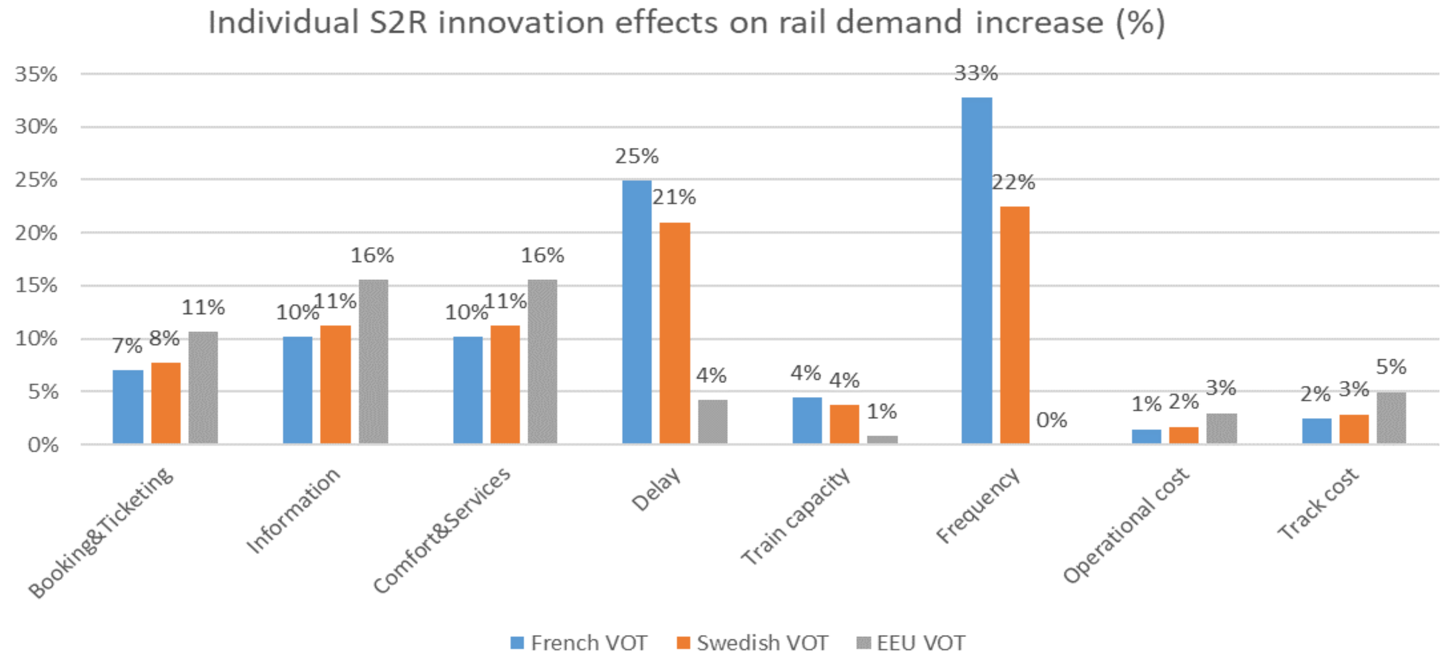
Results: Regional

- 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



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

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

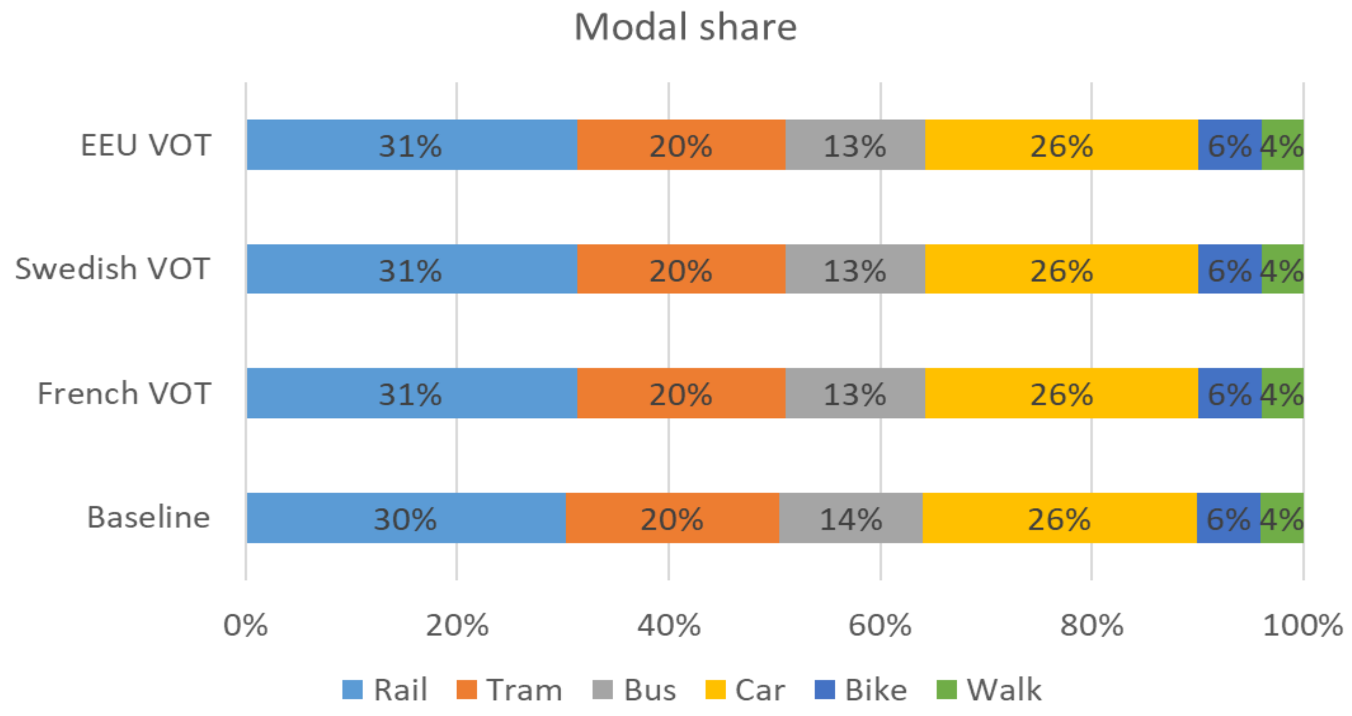
Improvements in S2R impact scenario – Metro

- 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

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

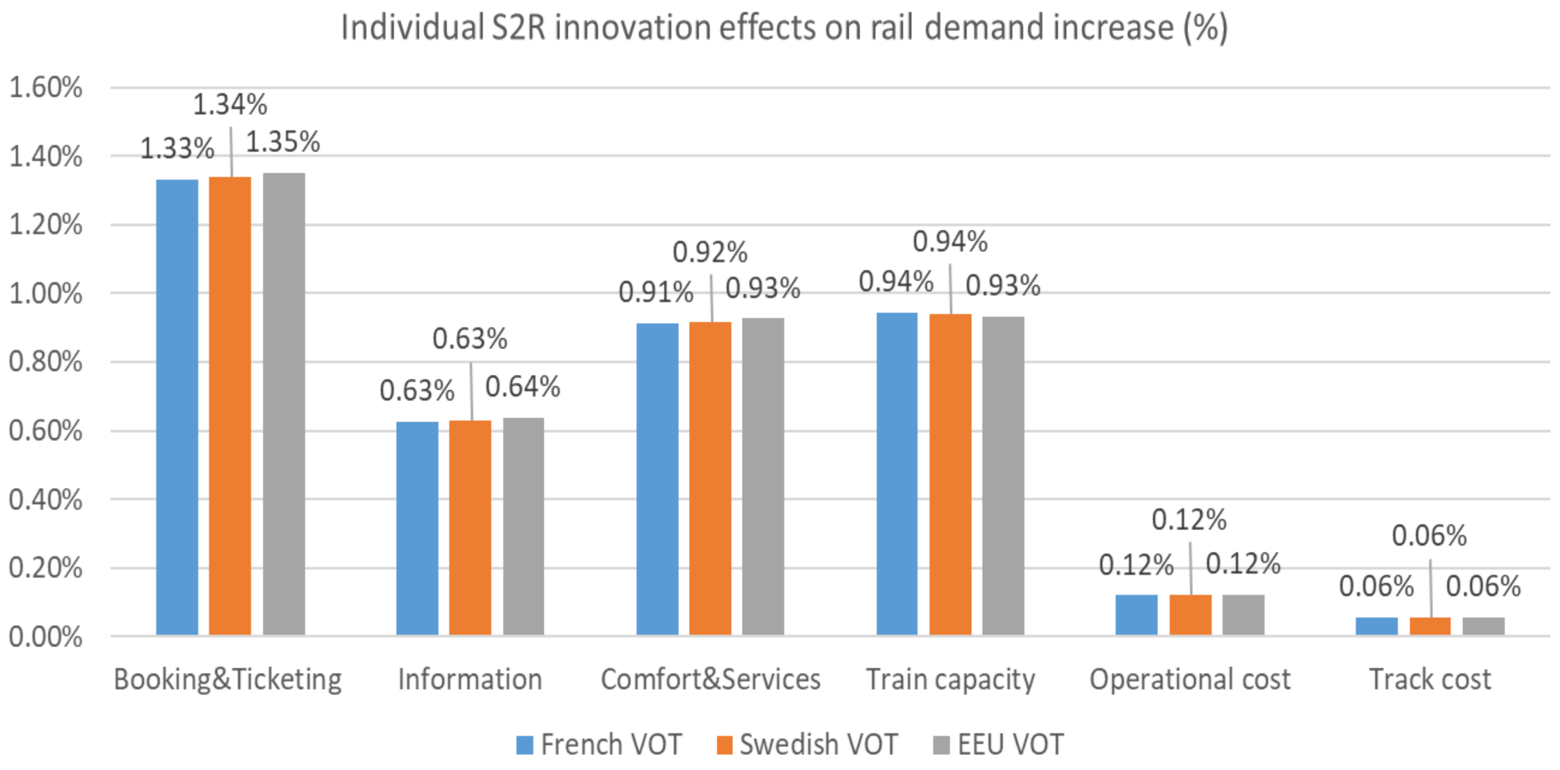
Results: Metro

- 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



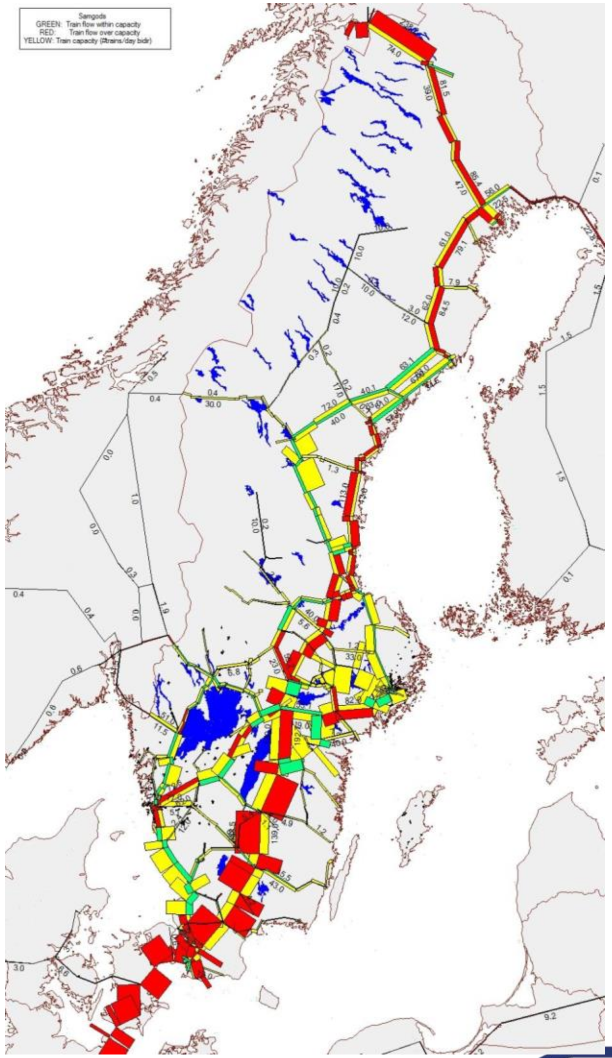
AV and EV scenario results – Metro

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

Scenario name	Rail mode share (%)	Ticket price (€)	Frequency	Load factor	Producer surplus (€)	Consumer surplus (€)
Baseline	30.3%	1.68	24	0.85	27413	0
Shift2Rail	31.2%	1.65	24	0.86	28314	4450
	(3%)	(-2%)	(0%)	(1%)	(3%)	/
Moderate AV	31.1%	1.65	24	0.86	28133	7778
	(3%)	(-2%)	(0%)	(1%)	(3%)	/
Moderate EV	30.6%	1.65	24	0.84	27700	15869
	(1%)	(-2%)	(0%)	(-1%)	(1%)	/
Optimistic AV	29.2%	1.65	24	0.81	26283	43079
	(-3%)	(-2%)	(0%)	(-5%)	(-4%)	/
Optimistic EV	29.6%	1.65	24	0.82	26629	36318
	(-2%)	(-2%)	(0%)	(-4%)	(-3%)	/

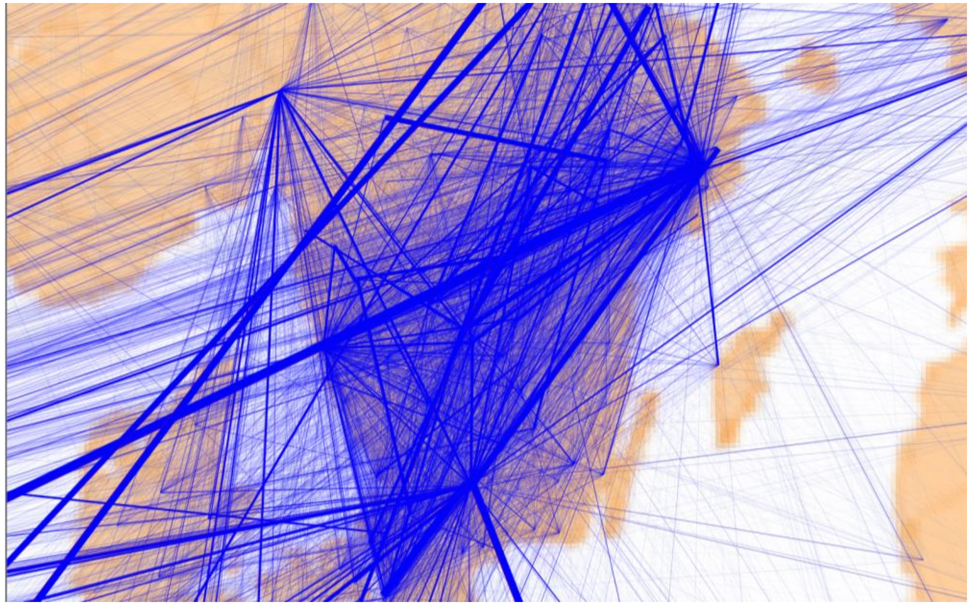
Samgods: capacity constraints on rail

- 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.



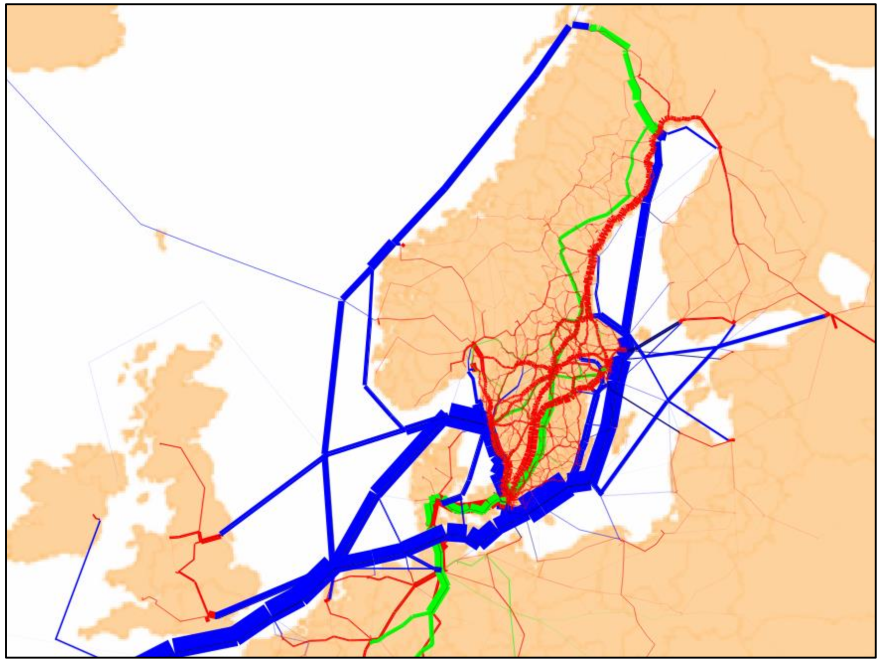
Samgods: cost minimizing model

- 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”

Input data item	Unit	Single wagon trains	Block trains	Combi trains
Average delay	min/train	-59%	-59%	-59%
Max load capacity	tonnes/train	+20%	+50%	+70%
Track capacity	trains/day	+5%	+5%	+5%
Operational cost (energy)	€/km	-10%	+20%	+70%
Operational cost (loco+wagon+labo ur)	€/h	-20%	-10%	0%
Track costs	€/km	-19%	-19%	-19%

”Time reductions”

Process time type	Unit	Single wagon trains	Block trains	Comb i trains
Loading/Unloading	h	-50%	-50%	-50%
Shunting at orig&dest terminals	h	-80%	-80%	-80%
Wagon&brake tests	h	-80%	-80%	-80%
Marshalling	h	-20%		-50%
Driving	h	-29%	-33%	-44%
(Un/load+shunting+ wagon&brake tests)	h	-56%	-56%	-56%

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)