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# Deliverable D 3.2
# SPD Specification

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# Table of Contents

# 1. Executive Summary

This deliverable summarizes the work performed in WP3 within the IMPACT-1 project, task 3.2 “Specification of SPDs”. The deliverable describes the proposed method for mode choice modelling. Two modelling strategies are proposed – one for passenger transport and one for freight transport. The deliverable is a preparation for the continuation work to be done in the follow-up project IMPACT-2.

## 2. Abbreviations and acronyms

| Abbreviation / Acronyms | Description |
|---|---|
| CCA | Cross-Cutting Activity |
| IMPACT | Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross-modal Transport chains |
| IP | Innovation Programme |
| KPI | Key Performance Indicator |
| LCC | Life Cycle Cost |
| MAAP | Multi-Annual Action Plan |
| SEIS | Socio-Economic Impact Study |
| SPD | System Platform Demonstrator |
| SPDIA | System Platform Demonstrator Integrated Assessment |
| TD | Technical Demonstrator |
| WA | Work Area |
| WP | Work Package |

# 3. Background

## 3.1 Relation to the Shift2Rail Work Programme and the IMPACT-1 Project

The present document constitutes the Deliverable D3.2 “SPD Specification” in the framework of the WA 1.2 System Platform Demonstrator (“Shift2Rail Multi-Annual Action Plan (MAAP)” 2015).

Increasing the competitiveness of the railway sector compared to other transportation modes is one of the major goals of Shift2Rail. It is thus important to assess to what extent the Shift2Rail innovations has an influence on the societal level and on mode choice in particular.

In WP3 “SPD definition” within the IMPACT-1 project (“Indicator Monitoring for a New Railway PAradigm in Seamlessly Integrated Cross Modal Transport Chains – Phase 1, Project Proposal” 2016), requirements and specifications are developed for Scenario Platform Demonstrators (SPDs) for four main service categories: high-speed passenger rail, regional passenger rail, urban passenger rail and rail freight. WP3 within IMPACT-1 is thus a pre-study which will result in a road map for the implementation of SPDs. The aim of the implemented SPDs is on the one hand that they should be able to assess the impact of Shift2Rail innovations on society (SEIS), especially the impact on mode choice. On the other hand, they will later be used for the integrated assessment (SPDIA) of the achievements of the technical developments of Shift2Rail using the KPI model of WP4. Therefore, the SPDs themselves form an important basis for the assessment of the target achievement of Shift2Rail (see Figure 1).

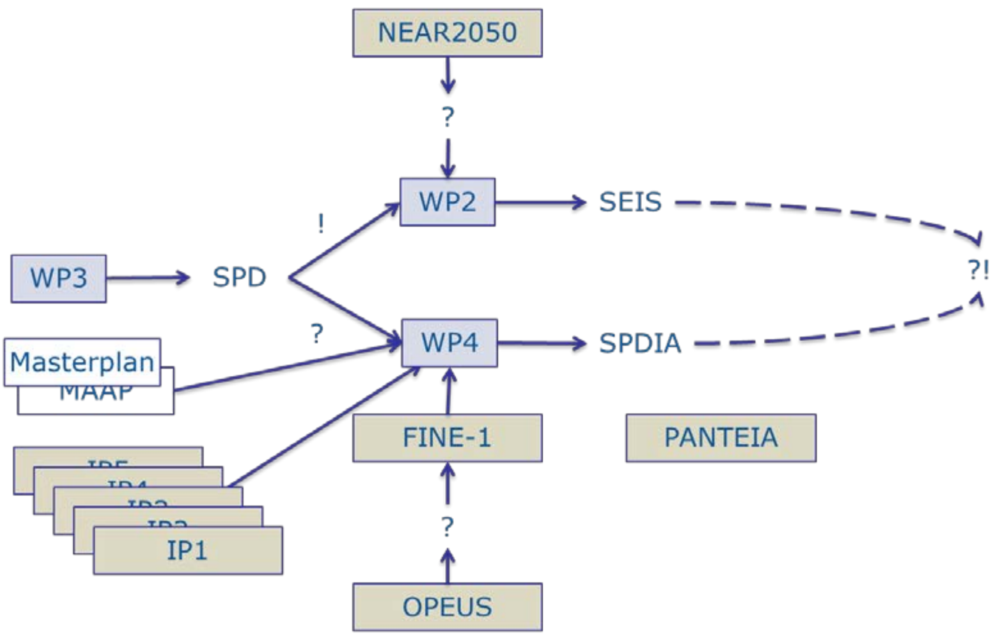


**Figure 1: Use of the SPDs both for the socio-economic impact study (SEIS) and the SPD integrated assessment (SPDIA) of IMPACT-1/2.**

The overall Shift2Rail objectives are described in the Shift2Rail Strategic Master Plan ("Shift2Rail Strategic Master Plan" 2015): to achieve a Single European Railway Area, enhance the attractiveness and competitiveness of the European railway system and to help the European industry to retain and consolidate its leadership on the global market, see also Figure 2.

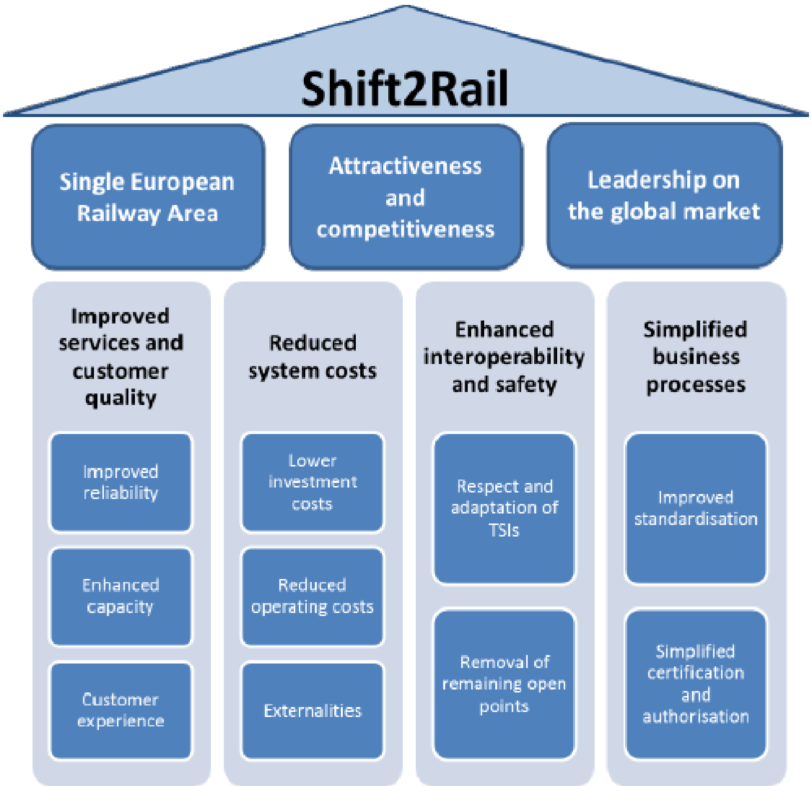


**Figure 2: Overall Shift2Rail objectives as described in the Master Plan ("Shift2Rail Strategic Master Plan" 2015).**

To achieve these objectives the Master Plan identifies five innovation programmes for the technical activities and five cross-cutting themes, the first of these cross-cutting themes being long-term needs and socio-economic research, see Figure 3. Shift2Rail thus encompasses both technical Innovation Programmes (IPs) and Cross-Cutting Activities (CCAs). IMPACT-1 is one of the CCA-projects within Shift2Rail.

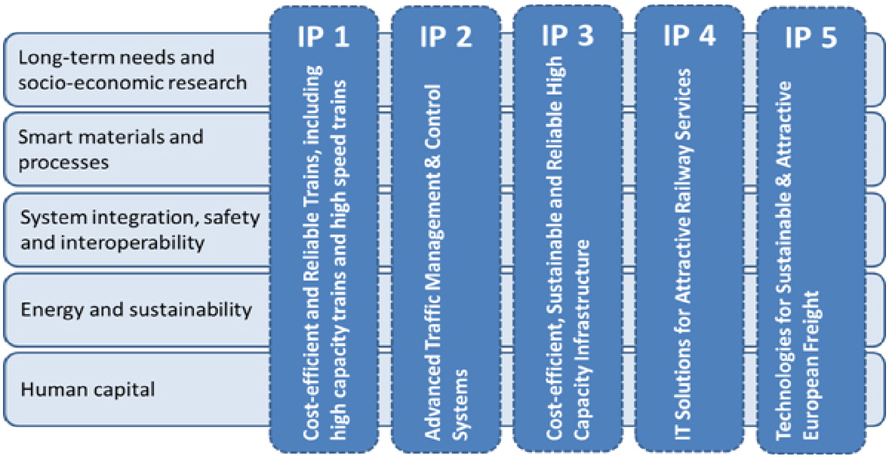


**Figure 3: Shift2Rail Innovation Programmes (IPs) and cross-cutting themes as defined in the Master Plan ("Shift2Rail Strategic Master Plan" 2015)**

The Multi-Annual Action Plan (MAAP) ("Shift2Rail Multi-Annual Action Plan (MAAP)" 2015) further specifies the work to be done within the long-term needs and socio-economic research cross-cutting theme and divides it into two work areas (WA): 1) Socio-economics and System Platform Demonstrators and 2) Key Performance Indicators, see Figure 4. The work in IMPACT-1/2 is done within work area 1 and 2 within the CCA activities of Shift2Rail.

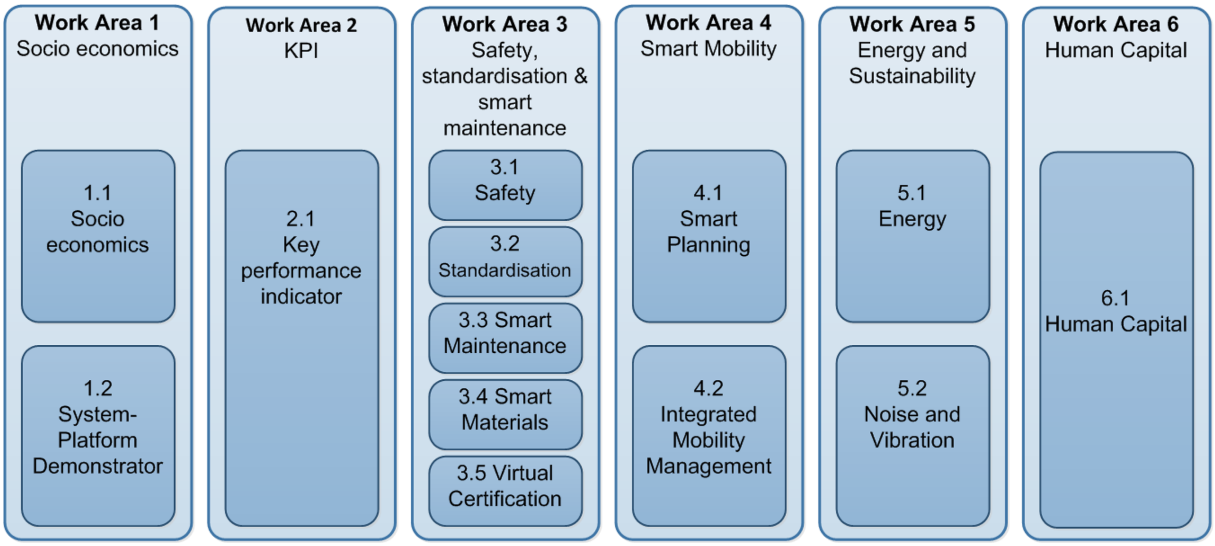


**Figure 4: Work areas within Shift2Rail cross-cutting themes as defined in the MAAP ("Shift2Rail Multi-Annual Action Plan (MAAP)" 2015) .**

The master plan ("Shift2Rail Strategic Master Plan" 2015) states three quantitative key performance indicators (KPIs): reliability, life-cycle cost (LCC) and capacity. Furthermore, the master plan describes one qualitative KPI, which is attractiveness.

The quantitative KPIs are defined in the IMPACT-1 document "Definition of Shift2Rail KPI" ("Definition of Shift2Rail KPI - Documentation within the IMPACT-1 Project. Document Status: First Issue." 2017). The success of Shift2Rail should be monitored by means of these KPIs. Key target levels have been set for the quantitative KPIs. The assessment of to what extent Shift2Rail reaches the key target levels for the quantitative KPIs is carried out within WP4 of the IMPACT-1/2 projects. Figure 5 shows the relation between WP2, WP3 and WP4 of the IMPACT-1/2 projects.

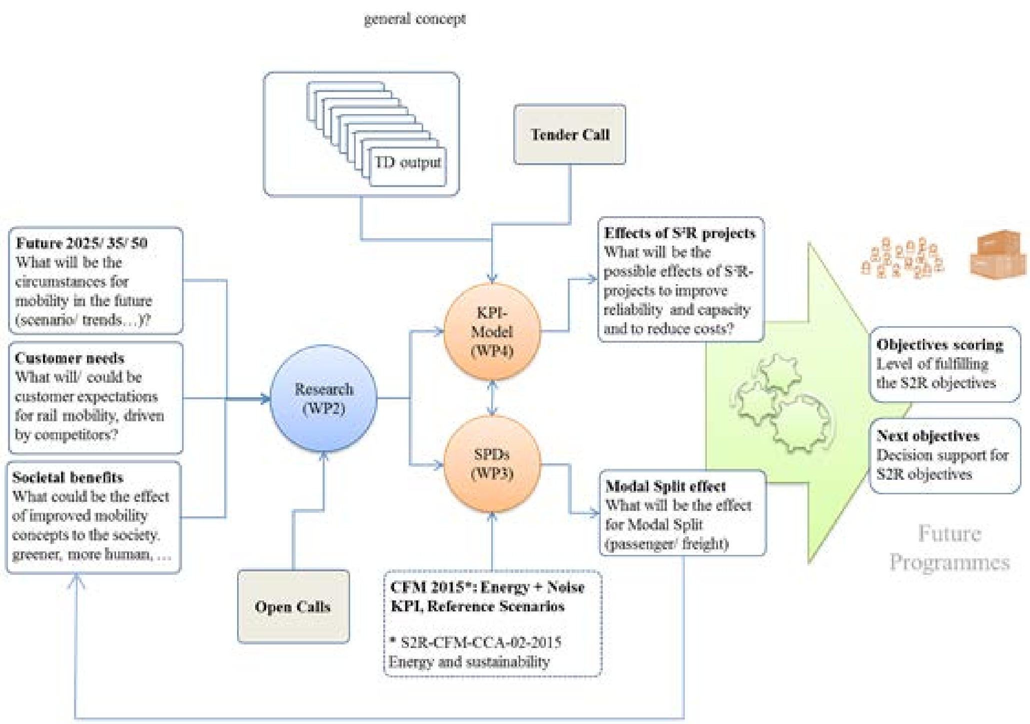


**Figure 5: Relation between the work packages of IMPACT-1/2.**

The key target levels specified in the master plan for the quantitative KPIs are:

1. 50% increase in the reliability and punctuality of rail services by 2030,
2. 50% reduction of the life-cycle cost of railway transport (i.e. the costs of developing, building, maintaining, operating, renewing and dismantling infrastructure and rolling stock) by 2030,
3. 100% increase in the capacity of the railway transport system by 2030.

## 3.2 SPD use cases

Mode choice effects will be evaluated for one use case for each market segment: high-speed passenger rail, regional passenger rail, urban passenger rail and rail freight. The use cases are spread around Europe and are based on requirements defined in D3.1 SPD Requirements (Kristoffersson 2017a), that enable all Shift2Rail innovations to be assessed using at least one use case. The use cases are described in more detail in D3.3 Use cases for SPDs (Kristoffersson 2017b).

# 4. Objective/Aim

This deliverable D3.2 belongs to WP3 within IMPACT-1, which is part of work area 1.2 System Platform Demonstrator. The purpose of D3.2 is to specify the methods and models that will be used in a later stage within the follow-up project IMPACT-2 to calculate mode choice effects of reaching the Shift2Rail key targets.

Even if the key targets described above are reached, the impact on mode choice, i.e. the ability of Shift2Rail to attract people and goods to railway transport, is still uncertain. There is a large body of literature on passenger mode choice as a reaction to changes in generalized cost of the different modes, as well as on the determinants of firms' mode choice. There are however missing links between e.g. decrease of life-cycle cost and its effects on the generalized cost for the rail alternative. This will be further investigated in WP2 of IMPACT-2.

For this deliverable, which is part of task 3.2 within WP3 in the project IMPACT-1 the main question is:

- Which methods/models shall we use in order to evaluate the Shift2Rail effect on mode choice, assuming that the key target levels are reached?

The purpose of this document is therefore to describe the methods/models that will be used later on in the follow-up project IMPACT-2 for calculation of mode choice effects.

# 5. SPD mode choice model specification for passenger transport

## 5.1 Background

Within IMPACT-1/2 three market segments for passenger transport shall be evaluated: high-speed rail, regional rail and urban rail. One important aspect is to be able to compare the three market segments. It is therefore important to have a common model type for all three passenger market segments, which is then applied to different use cases, see D3.3 (Kristoffersson 2017b, 3). Using different models for the three market segments would inevitably imply comparing apples with pears. Furthermore, elasticities and cross-elasticities are not available for the specific use cases under study. A common model for all three corridors that uses elasticities and cross-elasticities from literature is therefore to prefer.

An improvement of the rail alternative decreases the generalized cost for the rail alternative. From the passengers' point of view this has the potential to lead to two user adaptations: First, travellers may change their mode of transport from competing modes (car, air etc.) to rail when rail becomes more attractive (maybe the most commonly acknowledged adaptation strategy). Second, the decreased generalized cost may generate completely new trips that were not done in the previous situation.

## 5.2 Proposed mode choice model

We define the demand effect as the change in demand ($\Delta D$), i.e. increase in number of rail passengers and decrease in number of passengers for competing modes, due to a number of improvements of the rail alternative, i.e. a reduction in the generalized cost for the rail alternative. The increase in number of rail passengers result from both newly generated trips and a modal shift from competing modes, as described in the previous section.

The proposed method is to use an elasticity model, which relates the change in the generalized cost of passenger rail to changes in demand for rail and competing modes, as described by Equation 1:

$$E_{own} = \frac{\Delta D_{rail}/D_{rail}}{\Delta GC_{rail}/GC_{rail}}, \qquad \textbf{Equation 1}$$

$$E_{cross} = \frac{\Delta D_{comp}/D_{comp}}{\Delta GC_{rail}/GC_{rail}},$$

Where $D$ is demand, $GC$ is generalized cost, $E_{own}$ is own elasticity, i.e. the percental change in demand for rail as a response to a percental change in generalized cost for rail, and $E_{cross}$ is cross elasticity, i.e. the percental change in demand for a competing mode as a response to a percentage change in generalized cost for rail. The generalized cost for rail ($GC_{rail}$) is further specified as:

$$GC_{rail} = \beta_1 T_{inv} + \beta_2 T_{wait} + \beta_3 T_{delay} + \beta_4 P + ASC_{rail}, \qquad \textbf{Equation 2}$$

Where $T_{inv}$ is average in-vehicle travel time, $T_{wait}$ is average waiting time, $T_{delay}$ is average delay time, $P$ is average travel cost (ticket price), $ASC_{rail}$ is the alternative specific constant for rail, and $\beta_1 - \beta_4$ are weighting parameters for the different components of the generalized cost. Furthermore, the value of in-vehicle time can be calculated as $\frac{\beta_1}{\beta_4}$, the value of waiting time as $\frac{\beta_2}{\beta_4}$ and the value of delay time as $\frac{\beta_3}{\beta_4}$. The constant $ASC_{rail}$ describes the attractiveness of the rail mode relative to competing mode(s), given that all other terms (travel time etc) are equal. Effects of travel information, booking and ticketing would therefore be captured by this constant.

It is proposed to use elasticities ($E_{own}, E_{cross}$ ), weighting parameters ($\beta_1 - \beta_4$) and any forecast effects of attractiveness on changes to the constant ($ASC_{rail}$) from literature. Candidate sources for these elasticities and parameters are the Passenger Demand Forecasting Handbook (Rail Delivery Group 2013), the Swedish national transport model Sampers (Beser and Algers 2002) or the High-Tool model (“HIGH-TOOL Model” 2016).

## 5.3 Use case specific data

For each use case (one use case for each passenger SPD: high-speed, regional and urban), it first needs to be established which are the main competing modes to rail[1]. Then data on passenger demand for the base year needs to be collected for both rail and the competing mode(s), e.g. by gathering information from existing travel surveys or similar. Furthermore, average in-vehicle travel time, average waiting time, average delay time and average travel cost need to be collected for the base situation for the rail alternative, see also the description in D3.4 Road map for SPD implementation.

## 5.4 Assumptions and limitations

The overall aim of the mode choice model is to calculate the Shift2Rail effect on passenger mode choice, assuming the key target levels described in Section 3.1 have been reached.

However, the key targets need to be translated into effects on the variables that are input to the mode choice model described above (see Equation 2 and Figure 5), i.e. the variables that are part of the generalized cost for rail transport in the corridor.

[1] Inter-modal trip chains will not be considered for passenger transport.

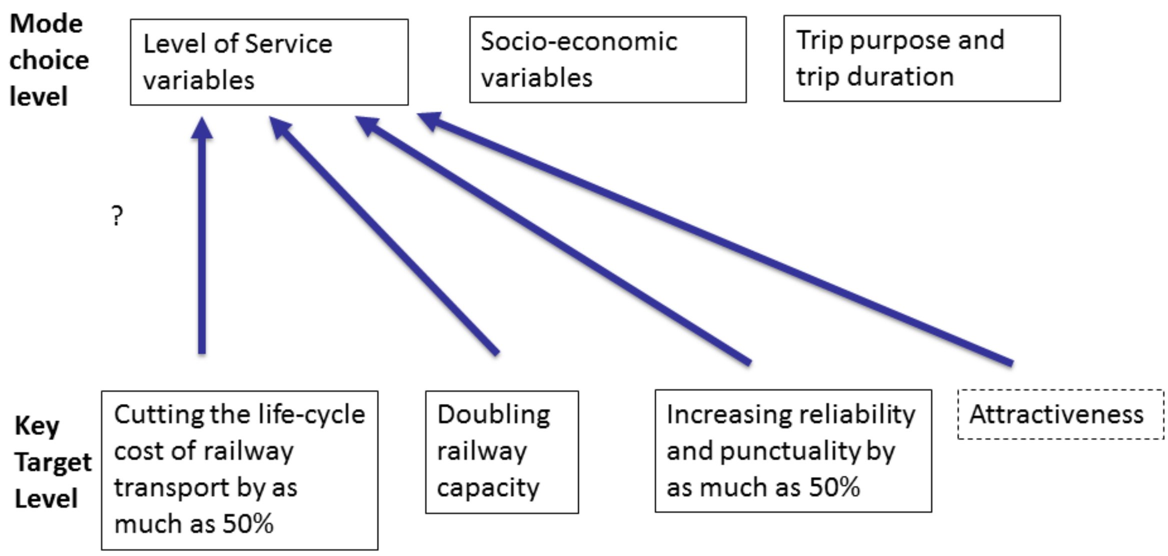


**Figure 6: Translation from key target level to mode choice level.**

For passenger transport the focus will be on effects of the quantitative key targets 1), 2) and 3) in Section 3.1, i.e. the effect of increased reliability, reduction in life-cycle cost and improvements in capacity. Effects of increase attractiveness, e.g. improvements in travel information and booking/ticketing systems, will be included if elasticities relating these improvements to changes in passenger demand is possible to find in the literature.

Some assumptions are needed when the key targets are translated into effects on the input data for the mode choice model:

- Train punctuality is defined for high-speed passenger rail and regional passenger rail in the IMPACT-1 document "Definition of Shift2Rail KPI" ("Definition of Shift2Rail KPI - Documentation within the IMPACT-1 Project. Document Status: First Issue." 2017) as the percent of passenger trains arriving with less than five minutes delay[2]. This definition solely focuses on the punctuality of the trains and is independent of passenger demand. From a socio-economic point of view, the cost of a delayed train is higher if it is full compared to if it is almost empty. The cost to the user is also much higher if the delay is 20 minutes compared to 5 minutes[3]. It is therefore not possible to use train punctuality in the generalized cost of the rail alternative (Equation 2) – rather we need to include the average delay time. In the situation when the key target levels are reached it is assumed that the average delay time is halved. The effects of interchanges and missed connections are not taken into account in this study.

[2] This definition of punctuality is not suitable for the urban passenger rail SPD, since the headway may in this case be as short as two minutes.

[3] Studies have shown that the relationship is even non-linear, i.e. that 20 minutes delay is perceived as more than four times as costly as a delay of 5 minutes.

- Life-cycle cost (of infrastructure and rolling stock) is within IMPACT-1 defined as the cost in Euro/passenger-km for the train operators (“Definition of Shift2Rail KPI - Documentation within the IMPACT-1 Project. Document Status: First Issue.” 2017). The relation between reductions in life-cycle cost and ticket prices is unclear and IMPACT-1 has so far not found any conclusive research in the field. WP2 will tackle this question within IMPACT-2, which means that estimates on this relation may come at a later stage. As a starting point, it will in this study however be assumed that a decrease of life-cycle cost by 50% will translate directly into 50% reduction in ticket prices.

- Capacity is within IMPACT-1 defined as the potential of people that could be transported per hour on a specific track, as a result of the combination of infrastructure, trains and signalling system (“Definition of Shift2Rail KPI - Documentation within the IMPACT-1 Project. Document Status: First Issue.” 2017). Increasing railway capacity can be done in different ways, either by introducing longer trains or double-decker trains with more seats, or by introducing more trains per hour on the track. More seats on the train will not change passenger in-vehicle or waiting time. Increasing the frequency of trains will decrease passenger waiting time and thereby have an impact on mode choice. It is in this study assumed that doubling railway capacity implies doubling of train frequency in the corridor under study.

The assumptions made in this study, both the assumption that key targets are reached, as well as the way key targets are translated into inputs to the mode choice model, represent the best-case situation from an increased demand for rail transport point of view. Therefore, the resulting demand effects can be seen as an upper bound on the number of passengers attracted to railway transport in the different use cases.

## 5.5 Expected results

Given all input data stated above, the demand model will calculate $\Delta D_{rail}$ and $\Delta D_{comp}$, i.e. the changes in passenger demand for rail and competing mode(s), see Equation 3. These results will then be used by WP2 in IMPACT-2 in order to calculate socio-economic benefits.

$$\Delta D_{rail} = \frac{E_{own} D_{rail} \Delta GC_{rail}}{GC_{rail}} \qquad \textbf{Equation 3}$$

$$\Delta D_{comp} = \frac{E_{cross} D_{comp} \Delta GC_{rail}}{GC_{rail}}$$

The own elasticity $E_{own}$ has been shown to be quite stable across countries and use cases. The cross elasticity $E_{cross}$ is however sensitive to the market share for rail in the situation when the elasticity was calculated. A sensitivity analysis with a high and a low cross elasticity value will therefore be performed within the study.

Given calculations from WP4 regarding the effects of Shift2Rail innovations on the quantified

KPIs (reliability, LCC and capacity), the input data to the mode choice model could be adapted with minor effort. However, it should be noted that the mode choice model will not easily be adapted to show effects of specific Shift2Rail innovations on passenger demand for rail transport.

# 6 SPD mode choice model specification for freight transport

## 6.1 Background

The literature review conducted in D3.1 (Kristoffersson 2017a) showed that for freight transport state-of-the-art European models follow the ADA-structure (aggregate-disaggregate-aggregate), in which freight mode choice is modelled within a logistics model for transport chain choice. This is also the case for the Swedish national freight transport model – Samgods (Swedish Transport Administration 2014).

## 6.2 Proposed mode choice model

Samgods models all freight traffic within, to, from and through Sweden (Bergquist, Bernhardsson, and Rosklint 2016). The modes modelled are road, rail, sea and air. Thus, rail freight transport from Germany, via Denmark to Sweden is modelled, which is the corridor chosen as use case for freight transport within Shift2Rail, see Figure 6. This is part of the Scandinavian-Mediterranean rail corridor. Samgods has been applied in (Vierth and Karlsson 2014) to simulate, compare and evaluate ten scenarios with longer trains and trucks on an intermodal freight corridor from central Sweden to the Ruhr area in Germany. The Samgods model is therefore proposed as the model to use for mode choice analysis within IMPACT-2.


**Figure 7: Example line for the cross-border use case of the rail freight SPD in Shift2Rail.**

## 6.3 Assumptions and limitations

For freight transport, the main focus of the mode choice analysis conducted in IMPACT-2 will be on the effects of increased capacity. Possibly, the analysis will also look into the effects of more efficient rail freight terminals. Punctuality is not currently included in Samgods, but we will look into the possibilities of including the effects of better punctuality on the transport cost.

The link between decreased LCC and modal shift is unclear for freight transport and cannot be captured using the Samgods model. The effects of decreased LCC will therefore not be analysed for rail freight transport in the IMPACT-2 project.

The base assumption will be that the Shift2Rail key targets are reached, i.e. a 100% increase in capacity. For freight, capacity is defined in (“Definition of Shift2Rail KPI - Documentation within the IMPACT-1 Project. Document Status: First Issue.” 2017) as the tons (or m³) of goods possible to transport per track km and per hour. This increase in capacity can be reached either by longer freight trains or by increasing the frequency of freight trains. Origin to destination transport cost is the most important variable in the freight mode choice model. This transport cost includes also the time and cost for transhipment. Both longer trains and increased frequency of freight trains impact the transport cost in the model. Longer trains by reducing the cost per ton-km (effects of economies of scale are modelled) and higher frequency by reducing the cost associated with waiting time.

In this study it is assumed that the increased capacity comes from both longer trains and increased frequency of freight trains and that they sum up so that the potential tons possible to transport are doubled.

## 6.4 Expected results

The mode choice model for freight transport will result in an estimate of the increase in ton-km of goods transported by rail and decrease in ton-km of goods transported by competing modes, given that the Shift2Rail key target levels are reached and given constant total demand. The results can then be used by WP2 in IMPACT-2 for socio-economic benefit calculations.

# 7 Conclusion

This Deliverable has described the methods and models proposed to use in the follow-up project IMPACT-2 for evaluation of increases in rail demand – caused either by a modal shift or by generation of new trips – given that the Shift2Rail key target levels are assumed to be reached. The demand models are outlined, and it is described which assumptions are needed in order to be able to apply these models. Furthermore, the Deliverable shows that modelling increased demand in the case of Shift2Rail key target levels being reached is doable and can give insights regarding the potential demand effects for the different SPDs.

# 8 Further Continuation: Road map for SPD implementation

The deliverable D3.4 of IMPACT-1 will describe the road map for implementing the mode choice models specified in this document and how the models will be applied to the use cases defined for each market segment.

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