IMPACT-1: Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains

D3.1

Requirements for SPDs

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Executive Summary

This deliverable summarizes the work performed in WP3.1 “Definition of requirements and desirable properties”. The deliverable describes a number of requirements on the System Platform Demonstrators (SPDs) needed in order for the SPDs to serve as a common ground for both the socio-economic impact analysis and the integrated assessment of key performance indicators (KPIs) to be performed within the cross-cutting activities of Shift2Rail. Requirements and desirable properties are outlined for the choice of line, train, track length, location and current situation.

This deliverable also contains a literature review which determines for each main service category (high-speed passenger rail, regional passenger rail, urban passenger rail and rail freight) the variables used as important factors in today´s state of the art transport models for modelling mode choice.

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1. Introduction

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 effect on the societal level and on mode choice in particular, but also to allow for an integrated assessment of the technological achievements of the Technical Demonstrators.

In WP3 “SPD definition” within the IMPACT-1 project, 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).

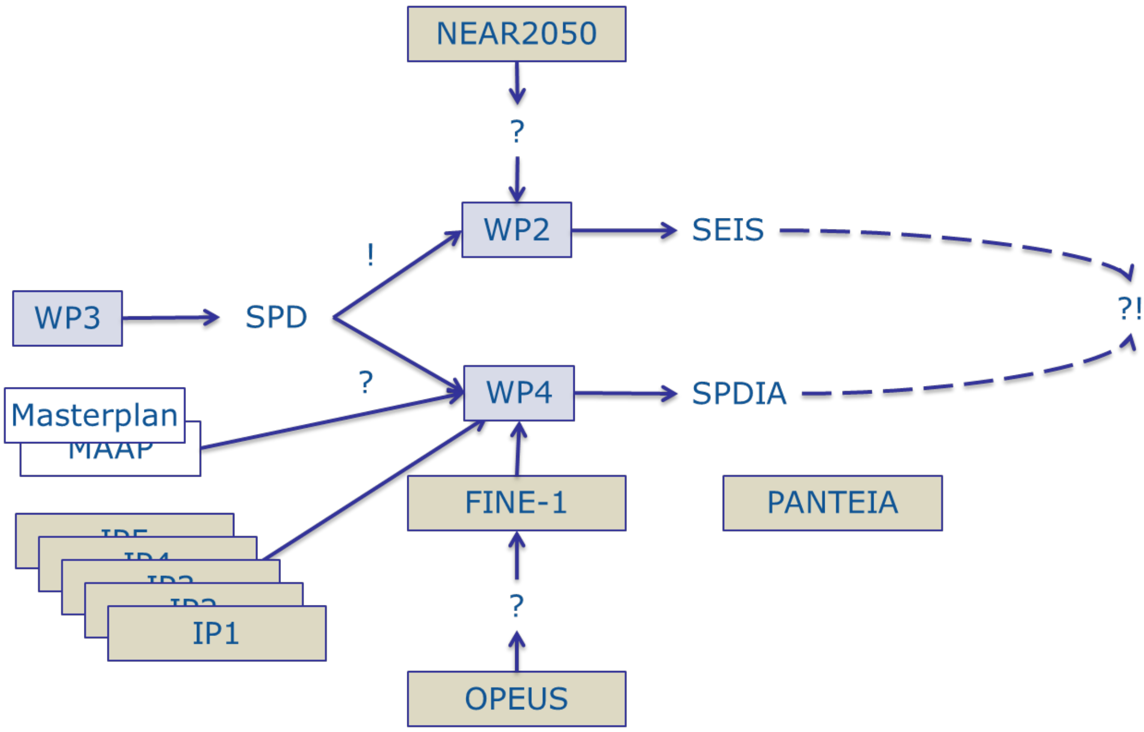

Figure 1: Use of the SPDs both for the socio-economic impact study (SEIS) and the SPD integrated assessment (SPDIA) of Shift2Rail.

WP3.1 constitutes the first step of the pre-study. Within WP3.1 general requirements on the SPDs are formulated and existing transportation models used today in order to predict demand for railway trips are reviewed for all four service categories. From the review conclusions are drawn concerning which parameters are most important for prediction of mode choice.

1.1 Relation to the Shift2Rail Work Programme and the IMPACT-1 Project

The overall Shift2Rail objectives are described in the Shift2Rail Strategic Master Plan (1): 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. 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 2.

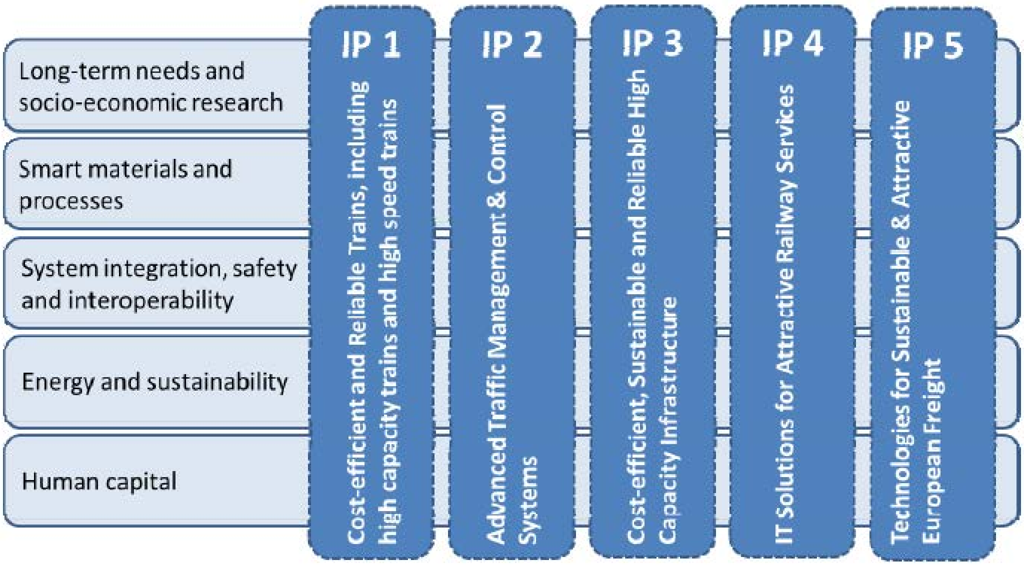

Figure 2: Shift2Rail Innovation Programmes (IPs) and cross-cutting themes as defined in the Master Plan (1)

The Multi-Annual Action Plan (MAAP) (2) 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 3.

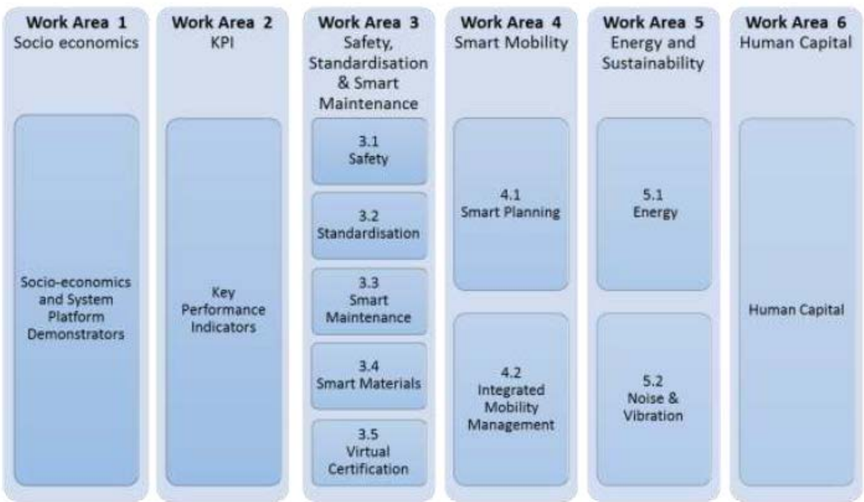

Figure 3: Work areas within Shift2Rail cross-cutting themes as defined in the MAAP (2) .

This deliverable “Requirements for SPDs” the first deliverable in WP3 within the project IMPACT-1 (3), which has started the work in work areas 1 and 2.

1.2 Purpose of the Document

This document has the purpose to describe the requirements for the definition of the System Platform Demonstrators (SPDs). Its purpose is also to review existing literature on state-of-the-art transport models that can be used to evaluate socio-economic impacts of rail improvements.

2. General requirements on the SPDs

The main purpose of this deliverable is to set up requirements for the four SPDs: high-speed passenger rail, regional passenger rail, urban passenger rail and rail freight. These main service categories has been defined within the Roll2Rail project with sub service categories, maximum speed and average station distance (4), see Table 1.

Table 1: Service categories as suggested within the Roll2Rail-project (4).

Main Service Category	Sub Service Category	Max. Speed (km/h)	Average Station Distance (km)
High speed	High speed 300	300	100-150
	High speed 250	250	80-120
	Intercity	200	25-50
Regional	Regional 160	160	10-25
	Regional 140	140	5-10
Urban	Suburban	120	3-5
	Metro	80	1.5-2.5
	Tram	50	0.3-0.8
Freight	Freight mainline	120	
	Freight shunting	40	

For the SPDs in IMPACT-1 one sub service category will be selected for each main service category. Use cases involving tram, light rail, metro, and shunting processes for freight are not considered in order to comply with the fixed number of four SPDs.

For operational reasons, requirements are also imposed on the track length of each SPD. Minimum track length depending on sub service category is defined in Table 2.

Table 2: Minimum track length depending on sub service category

Sub service category	Minimum track length (km)
High speed 300	300
Regional 160	250
Suburban 120	40
Freight mainline	300

To assure a generic profile and timeliness the following general requirements are posed on the SPDs:

- Rolling stock and railway lines should be mixable
- The condition of selected track should be at the state of 2013
- The selected rolling stock was in series application in 2013

To avoid boundary conditions the following requirement is posed on the SPDs:

- Clearance gauge, train control and power system should not have to be accounted for

For data availability reasons, the following requirements are posed on the SPDs:

- Selected rolling stock should, if possible, come from the following manufacturers: Alstom, Bombardier, CAF and Siemens.

- Selected railway lines should, if possible, be under the responsibility of the following network operators: DB Germany, SNCF France, Network Rail UK, Trafikverket Sweden, ÖBB Austria, SBB Switzerland, TCDD Turkey and CP Portugal.
- Selected freight trains should, if possible, consist of freight wagons from Tatravagonka and Waggonbau Niesky.
- Selected railway lines should be located at places where a transport model is available, which can be used as basis for further modelling of modal effects of S2R innovations.
- Selected railway lines should be subject to possible scope of improvement concerning share of traffic by rail mode.

In order to be able to use the SPDs in the socio-economic impact study the S2R key targets need to:

- be clearly defined to serve as input to the socio-ecnomic impact study, and
- be translated into variables that are input to mode choice models.

The last bullet point underlines the importance of converting S2R key targets into effects on variables that are input to existing mode choice models, see also Figure 4. Thus, knowledge of variables used in state-of-the-art mode choice models are of key importance. The next chapter is therefore devoted to a literature review of variables important for mode choice in the four main service categories.

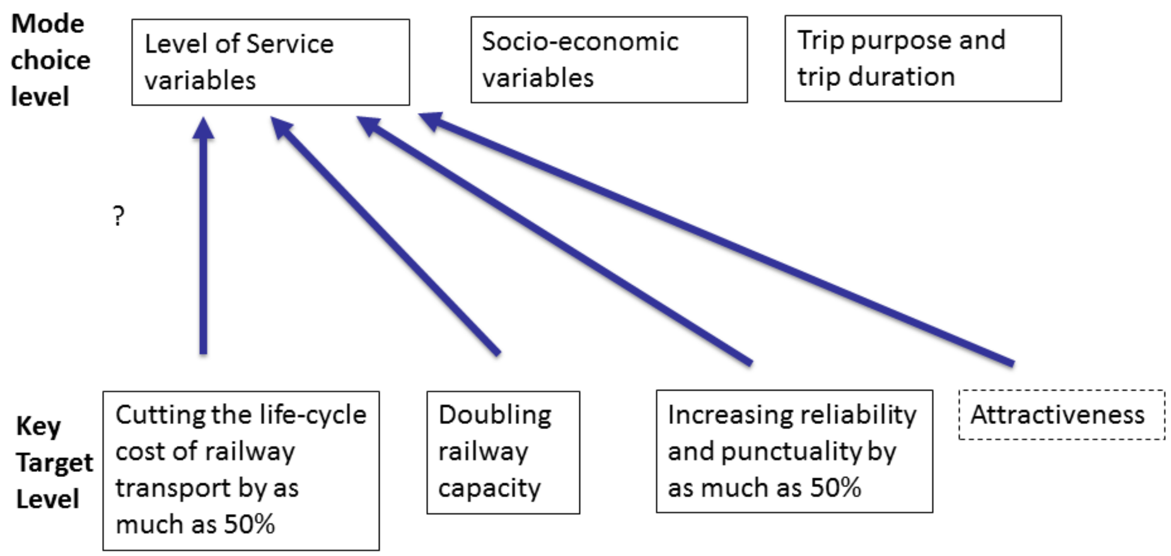

Figure 4: Relation between S2R key targets and input to mode choice models.(attractiveness is an example for additional objectives of S2R but without figure based monitoring)

3. Literature study on parameters important for mode choice

This literature study on parameters important for mode choice will cover the four service categories high-speed, regional, urban and freight described in the previous chapter. These four service categories have been defined with sub service categories, maximum speed and average station distance within the Roll2Rail EU-project (4), see Table 1.

In transport modelling it is praxis to divide models into long-distance and short-distance models. Therefore, there is a need to map the main service categories on models defined by trip distance. The High-speed category can be linked to long-distance passenger transport and the regional and urban categories both belong to the short-distance passenger transport, see Table 3.

The cut-off point for where a trip belongs to long-distance or short-distance differ among countries (5), where the US traditionally has used 100 miles (167 km), UK 50 miles (83 km) and Sweden, Norway and the European long-distance travel mobility survey 100 km as a cut-off point. Here, 100 km will be used since this seems to be the most common cut-off point in the European setting.

Table 3: Service categories as suggested in (4) combined with categories of transportation models

Main Service Category	Sub Service Category	Max. Speed (km/h)	Average Station Distance (km)	Transport Model Category
High speed	High speed 300	300	100-150	Long-distance passenger transport models for trips >100km
	High speed 250	250	80-120	
	Intercity	200	25-50	
Regional	Regional 160	160	10-25	Short-distance passenger transport models for trips <100km or a stand-alone urban model for a city
	Regional 140	140	5-10	
Urban	Suburban	120	3-5	
	Metro	80	1.5-2.5	
	Tram	50	0.3-0.8	
Freight	Freight mainline	120		Freight transport models
	Freight shunting	40		

It should be noted that mode choice is closely coupled with destination choice and therefore these are often estimated in the same model.

A delimitation in this literature study is that only European literature will be considered.

3.1 High-speed passenger rail

3.1.1 TransTools' long-distance model

At the long-distance and regional levels an EU-project called TransTools3 is currently ongoing (6). TransTools3 is an attempt to develop European wide transport models for both passenger and freight transport. The project is not finished yet, but the demand models for both passenger (7) and freight traffic (8) have been delivered. Two models have been estimated for passenger transport – a long-distance model for trips longer than 100 km and a short-distance model for trips shorter than 100 km. Both models include choice of frequency, destination and mode. The models cover 42 European countries and include also connections to world zones.

For the service category high-speed passenger rail, the long-distance model developed in TransTools3 is relevant. The development of the long-distance model for passenger transport build upon previous work in TransTools2, where first model estimations for a long-distance travel demand model for Europe was undertaken (9). This work continued in TransTools3 and lead to an updated demand model (10). The estimation of the TransTools' long-distance model is based on data from the DATELINE survey in 2001. The model includes four modes: air, car, bus, rail. There are two trip purposes in the model: business and private. The two trip purposes are further divided into sub-purposes based on number of nights away (trip duration). Business trips are divided into three sub-purposes: 0 nights away, 1-3 nights away and 4+ nights away. Private trips are divided into four sub-purposes: 0 nights away, 1-3 nights away, 4-6 nights away and 7+ nights away. For each of these sub-purposes nested logit models for choice of mode and destination are estimated, as well as multinomial logit models for the choice of making 0, 1 or 2 trips.

Since focus of this review is on parameters important for mode choice, the parameters in the models for mode and destination choice are described here in more detail. In the estimation of the mode and destination choice models the authors use fixed values of time (VoT) dependent on mode, trip purpose, distance and income, which they obtain from a meta-analysis by Wardman et al. (11). This means that parameters cannot be estimated for time and cost separately since they are related by the fixed VoT. The business models contain access time, wait time, in-vehicle time, monetary cost (there is however no cost available for bus and rail), a dummy for domestic destination, and alternative specific constants for all modes except car which is then the reference mode. Access to car in household was not significant in the business model. The authors note that the importance of travel time and cost decrease with increased number of nights away.

The model for private trips contains the same variables as the business model, but here the parameter for car in household turns out significant and increases the probability of choosing car as mode for the trip. A sensitivity analysis is performed by increasing the cost for car and air (for which monetary cost is available) by +/- 10% and analysing the effect on vehicle miles travelled (VMT). This test shows that private trips are more elastic than business trips (as expected) and that the price elasticity for air is in general low.

3.1.2 National long-distance models

Except for the TransTools project, most model development for long-distance passenger trips has been carried out in the context of national model system development (9). Several countries have national models. There exist national transport model systems, including models for long-distance travel, in e.g. Sweden (12), Norway (13), Denmark (14), the Netherlands (13) and Italy (15). An overview of European national models are given in (16). According to (9), the models for the Netherlands and Sweden are the most influential models and also the best documented, even though they also seem to be under-published.

The Swedish long-distance model has been re-estimated and updated in 2012 (17). The current model is segmented into three trip purposes: business, private and work trips and the included modes are car, bus, rail and air. Mode choice is mainly explained by travel cost, in-vehicle travel time, access travel time, wait time, access to car in household and gender. Application of the Swedish model in order to predict demand for high-speed rail has been done in Börjesson, 2014 (18).

The Netherlands national model system was most likely the first disaggregate (at person level) travel demand forecasting system, which was introduced in 1986. It has a common mode and destination choice model for both long- and short-distance trips. The model for business trips had from the beginning a separate long-distance model for trips longer than 40km, but that model was dropped around year 1990. The mode and destination choice model includes five modes and as many as eight trip purposes (Table 4).

Two long-distance models found in the literature without direct coupling to a national model system are models for Germany (19) and the UK (20).

3.1.3 Model comparison for long-distance passenger transport

Reviewed models for long-distance passenger transport are compared in Table 4. The mode choice models contain to a large extent similar type of parameters. They can be divided into **trip characteristic variables** (purpose, duration and domestic/abroad), **level-of-service variables** (travel cost, travel time, frequency etc.) and **socio-economic variables** (gender, age, household size, access to car in household etc.).

Table 4: Variables important for mode choice for long-distance passenger transport

	TransTools3	Sweden	Germany[1]	The Netherlands	Norway	The UK
Trip purpose	Business Private	Business Private Work	Trip purpose endogeneous variable	Work Business NHB[2] business Education Shopping Other Childrens Education Other children's travel	Work_Education Business Social Recreation Services_Other	Commute Business Leisure
Trip duration - nights away	0/1–3/4–6/7+	0/1–2/3–5/6+				
Trip length cut-off	>100km	>100km	>50km flexible	Long- and short-distance in the same model	>100km	> 83km
Modelled modes	Car Bus Rail Air	Car Bus Rail Air	Car Rail Air Bus	CarD CarP Train BusTramMetro Slow	Car Bus Rail Boat Air	Car Bus Rail Air
Logit model structure	Mode above destination	Mode above destination	Only mode	Mode-destination order dependent on trip purpose	Mode above destination	Mode[3] above destination
Mode choice variables						
Mode specific travel cost	X	X	X	X	X	X

[1] Has to be updated with the current used simulation tools
[2] NHB – Non-Home-Based
[3] Also within the mode level a nest is applied with PT above Air/Rail/Bus

Mode specific in-vehicle travel time	X	X	X	X	X	X
Non-linear transformations of travel time and/or cost	X	X	X	X	X	
Mode specific access/egress time[4]	X	X	x	X	X	X
Mode specific waiting time[4]	X	X	x	X		X
Frequency[4]			X		X	X
Number of transfers[4]			X			X
Crowding penalty						X
Trip abroad/domestic	X		X			
Access to car in household	X	X	x	X		X
Licence holding				X		
Trip purpose		X (private purposes)	X			
Gender		X	X	X		X
Age class			X	X		
Employment status /Working full or part time			X	X		X
Single/multiple person household			X			
Income		X	(x)	X	X	X
Alternative specific constants	X	X	X	X	X	X

3.2 Regional passenger rail

3.2.1 TransTools' short-distance model

The short-distance passenger travel models in TransTools (10) consider trips shorter than 100 km. The model structure is similar to the long-distance model, covering mode and destination choice as well as trip generation using logit models. The short-distance model is however based on another data source – the ETISplus data. A problem with this data is that most trips are intrazonal. Furthermore, seven modes are included in the short-distance models: Walk, tram/metro, bike, rail, car as driver, coach/bus, car as passenger. Also, the number of trip purposes differ from the long-distance model, with three trip purposes estimated for the short-distance model: business, private

[4] Not applicable to car and slow modes

and commute. The models for mode and destination choice contain the variables travel cost, in-vehicle travel time, access travel time, frequency, access to car in household, intrazonal radius for the different modes, total employment and total population in destination zone and alternative specific constants for each mode except car as driver, which is then the reference mode. Due to the high share of intra-zonal trips, the authors stress that the predictive capability may be low for short range urban trips.

3.2.2 National short-distance models

Also for regional trips, a lot of work has been carried out within the context of national model systems in Europe. As described above, the Netherlands model do not differentiate between long- and short-distance trips, rather they use the same demand model for both, the main reason being that trips longer than 100 km tend to cross the country boarder. The Netherlands short-distance model is therefore the same as the long-distance model described above. The Swedish short-distance-model is, just like the long-distance model, part of the national model system Sampers (12). It models tours shorter than 100km (one-way) in five regional models. The Norwegian model system (13) also separate between long- and short-distance travel models, with the same cut-off point of 100 km. Destination choice is however not modelled in the Norwegian short-distance model, since the zonal network was not detailed enough, which implied that the majority of trips less than 100km had origin and destination within the same zone. Instead distance bands were defined.

3.2.3 Model comparison for short-distance passenger transport

Reviewed models for short-distance passenger transport are compared in Table 5. As for long-distance passenger transport, they can be divided into trip characteristic variables (purpose), level-of-service variables (travel cost, travel time, frequency etc.) and socio-economic variables (gender, age, access to car in household etc.).

Table 5: Variables important for mode choice for short-distance passenger transport

	TransTools3	**Sweden**	**The Netherlands**	**Norway**
Trip purpose	Business Private Commuting	Work Business School Social Recreation Other	Work Business NHB business Education Shopping Other Childrens Education Other children's travel	Commuting Home-based business Work-based business Education Shopping and services Social visits Other
Trip length cut-off	<100km	<100km	Long- and short-distance in the same model	<100km
Modelled modes	CarD CarP TramMetro Rail Bus Walk Bike	CarD CarP PT Walk Bike	CarD CarP Train BusTramMetro WalkBike	CarD CarP PT WalkBike

Logit model structure	Modes above Intrazonal/Interzonal above destinations	Modes above destinations	Mode-destination order dependent on trip purpose	Only Mode (with distance bands)
Mode choice variables				
Mode specific travel cost	X	X	X	X
Mode specific distance		X		X
Mode specific in-vehicle travel time	X	X	X	X
Non-linear transformations of travel time and/or cost			X	X
Mode specific access/egress time	X	X	X	
Mode specific waiting time		X	X	
Frequency	X			
Access to car in household	X		X	X
Licence holding		X	X	
Car competition in household (licences/cars)		X		
Trip purpose				
Gender		X	X	X
Age class		X (Non-work)	X	X
Employment status /Working full or part time		X	X	
Single/multiple person household/Number of children in household				X
Season		X		
Income			X	X
Density				X
Intrazonal	X	X		

Alternative specific constants	X	X	X	X

3.3 Urban passenger rail

Several European cities use transport models to model the demand for trips with different modes. Sometimes the regional models described above are used also for urban travel and sometimes separate city models are used. This section will review a number of city models, keeping in mind that short-distance regional models are also often used for mode choice analysis of infrastructure investments or policy implementations in cities.

3.3.1 Urban models

Wegener (21) reviews twenty urban modelling centres for combined land-use and transport modelling, but most of these are non-European. Identified European modelling centres are London, Cambridge, Stockholm, Dortmund, Paris and Turin. Three of the first European integrated urban land-use and transport models were MEPLAN (applied to Bilbao, Leeds and Dortmund) (22), DELTA (23) and URBANSIM (24).

In the last decades, the development in urban transport modelling has been towards more disaggregate activity-based demand modelling and micro-simulation for network analysis, resulting in models such as MATSim (25) applied to a large number of areas. Microsimulation models require however large amounts of data and long run times and a trade-off is therefore needed between detail and practical application possibilities (26).

For this review, included variables in the mode choice models are of most importance, but these are not always reported. For example, for Berlin two models exists, a macro-model (implemented in Visum) and a micro model (implemented in Matsim). Both of these models are described in Neumann et al (27) but not with enough detail to conclude on the applied mode choice parameters.

Table 6 below show results for a number of cities where the variables included in mode choice were reported in the literature. The models for Paris and Copenhagen are described in Fox et al (13) and the model for Barcelona in Asenio (28).

Table 6: Variables important for mode choice for urban passenger transport

	Paris (Ile de France)	**Copenhagen**	**Barcelona**
Trip purpose	Commute – white collar Commute – blue collar Business Education for children Education for students DailyWeekly shopping Other shopping SocialRecreationalOther Work-based business Work-based other	Business Commuting Education Leisure	Commuting

Modelled modes	CarD CarP TwoWheeledWalk Rail Metro Bus Rail-Metro Rail-Bus Metro-Bus Rail-Metro-Bus Car-Rail Car-bus Car-Rail-Metro	CarD CarP Bus Train Walk Bike Light-rail	Car Bus Rail
Logit model structure	Modes above destinations	Separate mode choice	Separate mode choice
Mode choice variables			
Mode specific travel cost	X	X	X
Mode specific distance	X		X
Mode specific in-vehicle travel time	X	X	X
Non-linear transformations of travel time and/or cost	X		
Parking time for car		X	
Mode specific access/egress time	X	X	X
Mode specific waiting time	X	X	X
Interchanges	X	X	
Licence holding	X		
Car competition in household (licences/cars)	X		
Gender			X
Income	X		X
Density			X
Alternative specific constants	X	X	X

3.4 Rail Freight

Traditional four-step modelling (trip generation, trip distribution, mode choice, route choice) from passenger transport is also suitable for freight transport, but each step needs to be modified since freight transport differ from passenger transport in a number of ways: decision-makers are much more diverse (e.g. operators, drivers, shippers, carriers), the items being transported are more diverse (from small parcel deliveries with many stops to heavy single bulk shipments) and it is more difficult to get disaggregate data due partially to confidentiality reasons (29).

Models for freight mode choice are reviewed in de Jong et al (29). In that paper, mode choice models are categorized into seven different categories: elasticity-based models, aggregate modal split models, neoclassical economic models, econometric direct demand models, disaggregate modal split models, microsimulation approach and multimodal network models. Figure 4 summarizes the advantages and disadvantages of each type of mode choice model.

Type of model	Advantages	Disadvantages
Elasticity based	Very limited data requirements Fast in application	Elasticities may not be transferable Only impact of single measures, no synergies
Aggregate mode split	Limited data requirements	Weak theoretical basis Little insight into causality Limited scope for policy effects
Neoclassical	Limited data requirements Theoretical basis	Hard to integrate in four-steps model
Direct demand	Limited data requirements	Hard to integrate in four-steps model
Disaggregate mode split	Theoretical basis Potential to include many causal variables and policy measures	Need disaggregate data (shipper or commodity survey and/or SP)
Microsimulation approach	Many behavioural choices Included links to theory	Either large data requirements or many assumptions on distributions
Multimodal network	Limited data requirements Theoretical basis Can include elastic demand and policies affecting generalized transport cost	Little insight into causality Mostly done with fixed demand

Figure 5: Advantages and disadvantages of different types of freight mode choice models (29).

Many freight models have an overall structure called ADA (aggregate-disaggregate-aggregate) models. The ADA structure is used by the newly developed Transtools' freight model (8), the national freight models of Denmark (30), Norway and Sweden (31) and the freight model developed for the Mobility Masterplan Flanders (32). Mode choice is in this type of model typically included within a disaggregate logistics model for transport chain choice. The transportation chain choice includes three types of choices: 1) choice of number of legs in the transportation chain 2) choice of consolidation and distribution centres for road and rail, as well as ports and airports and 3) choice of mode for each leg (31).

A recent Swedish study investigates which the determinants are for mode choice in freight transport (33). The authors identify the shipment attributes (value, damage sensitivity, time sensitivity, weight, density and volume) as well as transport distance as two important determinants of freight mode choice. For a non-negligible share of the flow of goods the properties of the transported good and the transport distance imply that only one mode is a realistic choice, in which case the decision maker can be said to be captive to this particular mode, and factors that usually influence the choice of mode does not have an impact. Furthermore, the authors conclude that extent to which modal characteristics such as delivery time, punctuality and transport cost affect modal choice is relatively small. Also, the authors identify promoting shipment of larger volumes and economies of scale as enablers of a shift to rail and sea transport.

3.5 Conclusions from literature review

For the three main service categories related to passenger transport the literature review has shown that it is important that the model includes trip characteristic variables (in particular trip purpose), level-of-service variables (in particular travel cost, in-vehicle travel time and frequency/wait time for public transport) and socio-economic variables (in particular gender, age and access to car in household). This review has shown a number of examples of countries/regions/cities for which state-of-the-art mode choice models exist.

For freight transport the literature review showed that most state-of-the-art European models (Transtools, national models for Denmark, Norway and Sweden, as well as the freight model developed for the Mobility Master Plan Flanders) follow the ADA-structure (aggregate-disaggregate-aggregate) and models freight mode choice within a logistics model for transport chain choice. Important determinants for freight mode choice are the shipment attributes (value, damage sensitivity, time sensitivity, weight, density and volume) as well as transport distance.

4. Further Continuation: Identification of potential SPDs

We here sketch the next steps to identify potential SPDs for each of the four main service categories.

The next steps to identify potential SPDs include to:

- Look for potential SPDs for each main service category that fulfil the requirements and desirable properties outlined in this document
- Describe the identified potential SPDs and submit them for review by relevant stakeholders
- If needed, revision of the identified potential SPDs based on input from the review
- Submit the identified potential SPDs for approval by the Shift2Rail joint undertaking

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