Deliverable D 4.2
Subsystem structure and sublevel KPIs

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1. Executive Summary

This document has the purpose to provide an overview over the qualitative structure of the model which will be used to assess the Key Performance Indicators (called “KPI model” in the reminder of the document) developed in WP4 of IMPACT-1, so that people who are not involved in the development of the model can understand the structure of it.

First, the targets, given by the Shift2Rail Master Plan [2], of reducing Life-Cycle Cost (LCC) by 50%, increasing Capacity by 100% and increasing Reliability & Punctuality by 50% will be further defined. For measuring these quite highly aggregated KPIs for such a complex system as the railway system a structure needs to be developed and used (Chapter 5.2.).

Additionally, there is the challenge to retrieve the knowledge from the technical experts about their specific part of the railway system, the so-called Technical Demonstrators (TD) and make it usable for contributing to a model reflecting the whole railway system. Therefore, next the interface to the TDs, the so-called Sublevel KPIs, is being described. These Sublevel KPIs will be used to make sure that every part of railway, which is influenced by Shift2Rail and can contribute to the targets, is included, even if they are very differing in sense of effect, typical measuring units, measuring method and others (Chapter 5.3.).

Finally, the connection of the interface to the TDs and the key targets is being described. This will build the qualitative KPI model. Because the sets of Sublevel KPIs from the different TDs need to be combined to estimate only three High level KPIs for the whole railway system, there is a subsystem structure of the railway system, which reflects it in a structural way and covers all TDs, being implemented (Chapter 5.4.).

Nevertheless, for this first qualitative KPI model a lot of assumptions, conditions and limitations exist and, besides transferring the qualitative model into a quantitative model, replacing those assumptions with valid data will be a major task in WP4 of IMPACT-2.

2. Abbreviations and acronyms

Abbreviation / Acronyms	**Description**
CCS	Control command and signalling
HVAC	Heating, ventilation and air conditioning
IP	Innovation Programmes
LCC	Life-Cycle Cost
MKBT	Mean Kilometre Between Failure
KPI	Key Performance Indicator
PRM	Person with Reduced Mobility
SEIS	Socio-Economic Impact Study
SPD	System Platform Demonstrator
SPDIA	System Platform Demonstrator Integrated Assessment
TCMS	Train Control & Management System
TD	Technical Demonstrator
TMS	Train Management System
UIC	Union internationale des chemins de fer
WP	Work Package

3. Background

The overall targets of Shift2Rail are defined in the Master Plan [2]. All TDs are contributing to those overall targets. Hence all TD-related WPs of the member-projects are requested to quantify their IMPACT on them. Non-necessarily are the KPI which quantify the results of one TD or WP a direct fraction of the overall KPI describing the quantified three Master Plan targets.

The relation of WA1.1, WA1.2 and WA2 is reflected in the WP-structure of IMPACT-1: The SEIA (WA1.1) is objective of WP2, the definition of the SPDs (WA1.2) objective of the WP3 and the modelling for the integrated assessment (WA2) objective of WP4. The relation of the WPs and the projects is shown in Fig. 1 below.

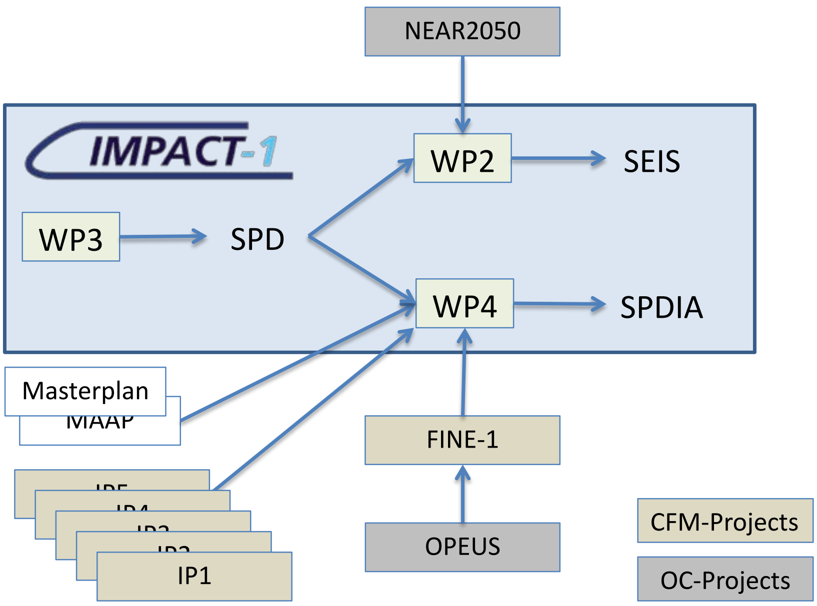

Figure 1. Project Interaction

The present document constitutes the Deliverable D4.2 “Subsystem structure and sublevel KPIs” in the framework of the WA 2, task 2 and task 3 of CCA defined in the Multi-Annual Action Plan at the time of the start of IMPACT-1 (September 2016) [1].

It also contributes to WA 1.2, task 2.3 and 2.4 CCA defined in the Multi-Annual Action Plan at the time of the start of IMPACT-1 (September 2016) [1].

4. Objective/Aim

This document has been prepared to provide an overview over the general structure of the KPI model developed in WP4 of IMPACT-1 and further refined in IMPACT-2.

Therefore, first the given through the Shift2Rail Master Plan [2] targets Life-Cycle Cost (LCC), Capacity and Reliability & Punctuality will be further defined. Then the interface to the Technical Demonstrators (TD), the so-called Sublevel KPIs, is going to be described. Hence the lowest and highest level of the model will be defined, and the model can be created by getting from the lowest level of the model to the targets. In the last part of this deliverable the approach for doing so will be described.

Thus, this deliverable will allow people who are not involved in the development of the model to understand the structure of the qualitative KPI model developed in WP4 of IMPACT-1.

5. Subsystem structure and sublevel KPIs

5.1. Concept of subsystem structure and sublevel KPI

For assessing highly aggregated KPIs like LCC, Capacity and Reliability &Punctuality for such a complex system as railways a structure needs to be developed and used. It is the aim of the model to include every part of railways which is influenced by Shift2Rail and can contribute to the targets called out by the Shift2Rail Masterplan [2], partly very differing components in sense of effect, typical measuring units, measuring method and others needs to be fit together and brought in line with the reachable target. This is also why existing models developed in other transport projects, such as Clean Sky (see Hainz, Meyer zu Hoerste & Brinkmann (2018) [4]), could not be simply adjusted to create a KPI model for the whole railway system.

Additionally, there is the challenge to make the knowledge of the technical experts about their specific part of the railway system usable for the contributing to a model reflecting the whole railway system. Therefore, the KPI model will be created by a combination of a top-down- and a bottom-up-approach.

The top of the model is defined be the key targets of Shift2Rail. Those so called “High level KPIs” are described in Chapter 5.2. The bottom will be the interface to the Technical Demonstrators (TD). A set of so called “Sublevel (or Interface) KPIs” will be discussed and agreed on with the leaders of the Technical Demonstrators. Those Sublevel KPIs should be at the highest level of the specific part of the railway sector, the specific TD is aiming for, the technical experts can provide. The Sublevel KPIs are further described in Chapter 5.3. In the KPI model the Sublevel KPIs will be connected to the High level KPIs (see Chapter 5.4.3.).

The sets of Sublevel KPIs from different TDs need to be combined to, in the end, estimate only three High level KPIs for the whole railway system. Therefore, a subsystem structure of the railway system is being implemented in the model, (see Chapter 5.4.3.).

5.2. High level KPIs (key targets)

5.2.1. LCC – Life Cycle Cost

5.2.1.1. LCC for passenger transport

Definition:

The LCC of the railway system to be measured for Shift2Rail covers all affected entities, cost categories and life cycle phases of the railway system which are directly addressed by the Shift2Rail TDs: costs of developing, building, maintaining, operating, renewing and dismantling rolling stock and infrastructure or any residual value it may have (e.g. selling of vehicle or its materials).

The costs considered at the highest level are the costs of the railway operators. All life cycle costs of the supplying industry are included in the procurement costs of the train operators: procurement, engineering, homologation, maintenance or dismantling costs.

As ticket prices for the customer are not part of Shift2Rail, this conversion is not taken into account.

Measuring unit:

- passenger transport LCC: [€/(passenger*km)] per SPD

Baseline:

The reference LCC for each SPD is defined in IMPACT-1 D4.1 - Reference Scenario [5].

5.2.1.2. LCC for freight transport

Definition:

The definition of LCC for passenger transport is equally applicable for freight transport by measuring metric ton kilometre instead of passenger kilometre.

Measuring unit:

- freight transport: [€/(metric ton*km)]

The costs include all costs of the transport chain including the loading and unloading process within the terminals.

5.2.2. Capacity

5.2.2.1. Capacity for passenger transport

Definition:

The capacity to be measured is defined as the potential of people that could be transported per peak hour on a specific track. This includes the combination of the capacity of the infrastructure, the trains and the signalling system.

As only peak hour is considered for passenger transport, capacity increase due to a reduction of maintenance hours will not be reflected for SPD1, SPD2 and SPD3.

Measuring unit:

- passenger transport: [available seats + standing room / track km-h]

This definition is the same as the one used for capacity measurement in the lighthouse project Roll2Rail [1].

Baseline:

The reference capacity for each SPD is defined in IMPACT-1 D4.1 - Reference Scenario [5].

5.2.2.2. Capacity for freight transport

Definition:

The capacity to be measured is defined as the potential of freight that could be transported per day on a specific track. This includes the combination of the capacity of the infrastructure (inclusive freight specific infrastructure), the trains (locomotives and waggons) and the signalling system.

Measuring unit:

- freight transport: [metric tons / day]

Baseline:

The reference capacity for each SPD is defined in IMPACT-1 D4.1 - Reference Scenario [5].

5.2.3. Reliability & Punctuality

5.2.3.1. Reliability & Punctuality for passenger transport

Definition:

Full Reliability & Punctuality is defined as 100% percentage of punctual trains. Since the actual punctuality of trains is already significantly higher than 67% (according to the definition given below), an increase of 50% is mathematically not possible. This aim is therefore interpreted as 50% reduction of unreliability.

A punctual train service is defined as the service which arrives at a strategic measuring point with less delay time than the defined one. Acceptable delay time definition per SPD as well as a definition of service time is specified IMPACT-1 D4.1 - Reference Scenario [5].
The percentage of punctual trains is calculated as the percentage of the number of services which arrive punctual compared to all train services.
This definition is the same as the one used for punctuality measurement in PRIME [3]. To have a significant number of services, the assessment period for calculation is one year.
Strategic measuring points are at least the destination station plus further points depending on SPDs and data availability, e.g. main interchange stations. The strategic measuring points for each SPD are specified in IMPACT-1 D4.1 - Reference Scenario [5].
Cancelled trains will be classified as unpunctual trains.

Measuring unit:

- 100% - number of unpunctual passenger trains compared to the total number of passenger trains [%]

Baseline:

The reference punctuality for each SPD is defined in IMPACT-1 D4.1 - Reference Scenario [5].

5.2.3.2. Reliability & Punctuality for freight transport

Definition:

The general definition of Reliability & Punctuality for passenger transport is equally applicable for freight transport, but the results will not be measured per passenger train but per freight train.

Measuring unit:

- 100% - number of freight trains delayed with less than 15 minutes compared to the total number of freight trains [%]

Baseline:

The reference punctuality for freight transport is defined in IMPACT-1 D4.1 - Reference Scenario [5].

5.3. Sublevel KPIs (Interface KPIs)

5.3.1. Sublevel KPIs for LCC model

Cost components relevant beyond the technical areas of the railway system:

Component **energy cost**: In the railway system there are different areas, which consume energy and therefore cause energy costs. For the first version of the KPI model, which will cover the main improvements achieved by Shift2Rail, only the energy consumption, which is needed for running trains, will be considered. This means that in this first model energy costs are train energy usage costs.

Component **labour cost**: In the railway system there are different professions, which can cause labour costs. Within the KPI model the labour cost component consist of the cost for the train driver only. Labour cost for maintenance is included in maintenance cost. Labour cost caused for the operation of freight handling assets, i. e. terminals and marshalling yards are part of the cost for using those assets. Other labour cost, e.g. for service personal or dispatchers, are not included in the model, as these are not foreseen to have a main impact on the costs.

Cost components relevant in all technical areas of the railway system:

Component **capital cost**: This concept includes the cost of engineering, manufacturing, validation, commissioning and certification of all assets in railway including the trainset components, components of CCS, components of the infrastructure and freight transport specific components.

Component **maintenance cost**: This concept includes all maintenance tasks’ cost, both preventive and corrective maintenance of all assets in railway including the trainset components, components of CCS, components of the infrastructure and freight transport specific components. Further all personnel costs, which are linked to maintenance activities, are included in maintenance cost.

Component **dismantling cost**: This concept includes the cost of selection of components to be recovered, recycled or reused after complete lifetime. For those components that cannot be recovered the cost of disposing residue, landfill or incineration is considered.

5.3.1.1. Sublevel KPIs for LCC model contributed by IP1 (Passenger Train)

The different costs that are included in the Sublevel KPIs for the LCC model are **capital costs, maintenance costs, dismantling cost** and **energy cost** for the passenger train.

All IP1 TDs contribute to capital and maintenance cost reduction with their developments in traction chain (TD1.1), TCMS evolution from cables TCMS to wireless TCMS (TD1.2), new carbody materials (TD1.3), new running gear technology and controls (TD1.4), advanced braking technology (TD1.5), advanced door systems (TD1.6) and new interiors' layout criteria (TD1.7).

Carbody TD (1.3) is the only one contributing significantly to dismantling cost reduction.

As for capital and maintenance cost, the components weight is also relevant for energy calculation. All TDs are contributing indirectly to energy usage reduction by reducing weight.

The LCC calculation is done for a complete fleet of trains, were the size of the fleet is crucial. The size is calculated in reference to the service to be given. **Fleet size** describes the required fleet size considering that not all the trains are able to be coupled together, considering different rolling stock types and Train Control & Management System (TCMS) versions. The concept is linked with the increased percentage of coupling possibilities due to the functional open coupling developed in TD1.2.

5.3.1.2. Sublevel KPIs for LCC model contributed by IP2 (CCS)

A first set of Sublevel KPIs were, without more detailing, used to asked TD leader for their assessment of possible improvements.
However, the description of the Sublevel KPIs did not always correlate with the data needed for the modelling approach as it was defined that only information for **capital** and **maintenance costs** are taken into account. For some TDs, the TD leaders were asked for improvements on "maintenance, personnel and energy costs". In this first step, these improvements were all subsumed in maintenance costs. Personnel costs as given for TD 2.6 (on-site testing) were assumed to be part of the capital costs, as we do not have maintenance costs for TD 2.6. Only the improvements for **Energy costs** were considered separately. Where a change in energy costs was given by the TD leader, it was used separately in the model. This was only done for TD 2.9 and 2.10.

TD2.1 has an impact on capital and maintenance costs for communication systems.

TD2.2 has an impact on capital and maintenance costs for train operation by providing solutions for automatic train operation systems.

TD2.3 has an impact on capital and maintenance costs for train operation by providing solutions for moving block technology.

TD2.4 has an impact on capital and maintenance costs for train positioning.

TD2.5 has an impact on capital and maintenance costs for train integrity.

TD2.6 has an impact on capital costs due to changes in the needed testing procedures.

TD2.7 has an impact on capital and maintenance costs due to changes process by using formal methods.

TD2.8 has an impact on capital and maintenance costs for train operation by providing solutions for virtual coupling.

TD2.9 has an impact on capital and maintenance costs for train operation by providing solutions for Traffic management systems

TD2.10 has an impact on capital and maintenance costs for wayside objects.

TD2.11 has an impact on capital and maintenance costs for the railway system due to incorporating methods for IT security.

Overall, regarding the validity of the given information, we assume the Sublevel KPIs as generally applicable and expect only minor changes. We expect that the numbers will be adapted once we had more in depth discussions with the TD leaders.

5.3.1.3. Sublevel KPIs for LCC model contributed by IP3 (Infrastructure)

The different costs that are included in the Sublevel KPIs for the LCC model are **capital costs**, **maintenance costs, installation and logistics costs**. Installation and logistics costs are however considered to be part of capital costs, which are defined as renewal costs and include costs for material as well as labour

TDs 3.1 and 3.2 have an impact on maintenance costs (Euros per asset and year) and capital costs (Euros per asset) for switches and crossings.

TDs 3.3 and 3.4 have an impact on maintenance costs (Euros per track-km and year) and capital costs (Euros per track-km) for tracks. The aim is to use euros per gross ton-km for the maintenance cost impact.

TD 3.5 has an impact on maintenance costs (Euros per asset and year) and capital costs (Euros per asset) for bridges and tunnels. This TD also has an impact on the number of load cycles of a bridge, which will decrease the life cycle cost of the asset. However, this impact is not included in the current version of the model.

TDs 3.6, 3.7 and 3.8 have an impact on maintenance costs (Euros per track-km and year).

TD 3.9 has an impact on maintenance costs (Euros per track-km and year) and capital costs (Euros per track-km) and for energy supply assets, as well as the energy cost (ct/kWh). Furthermore, the closely related TD 3.10 also has an impact on the capital cost (Euros per track-km) of the energy supply assets.

TD 3.11 has an impact on maintenance costs (Euros per m^2 and year) and capital costs (Euros per m^2) for passenger stations.

5.3.1.4. Sublevel KPIs for LCC model contributed by IP5 (Freight)

As IP5 is targeting the whole freight rail transport, the Sublevel KPIs do not only have to cover certain KPIs of technologies, but also KPIs concerning the operational part. Therefore, the LCC of freight traffic consists of the following parts:

- Locomotives
- Waggons
- Marshalling yards
- Terminals and
- Operation

TD 5.1 “Fleet digitalisation and automation” has an impact on the **energy and personal costs** as on the **average speed**.

TD 5.2 “Digital transport management” has an impact on the **infrastructure, staff, energy** and **shunting loco costs of marshalling yards and terminals**. Further it has an impact on the **load factor** and the **yearly km** of locomotives and waggons.

TD 5.3 “Smart freight waggon concepts” has an impact on **capital cost, maintenance cost** and **yearly km** of freight waggons.

TD 5.4 “New freight propulsion system” has an impact on **capital cost, maintenance cost** and **energy costs** of locomotives. Further TD 5.4 has an impact on the **train length** and **number of waggons** per train.

5.3.2. Sublevel KPIs for Capacity model

5.3.2.1. Sublevel KPIs for Capacity model contributed by IP1 (Passenger train)

For IP1, weight reduction is linked to the amount of passengers. For each tone reduction, extra people could be accepted within the train. All IP1 TDs contribute to **weight reduction**. However, the impact of some TDs is bigger than others. The share between traction (TD1.1), carbody (TD1.3) and running gear (TD1.4) is the most significant. The rest of TDs contribute less significantly.

However, the main impact of IP1 developments on capacity is due to the **Wireless coupling ability**. This concept describes the coupling time improvement of two consist trains at an intermediate stop. The baseline state of the art is the conventional coupling, while the improved type is wireless coupling. This enables an increase of track capacity by reducing the journey time.

5.3.2.2. Sublevel KPIs for Capacity model contributed by IP2 (CCS)

A first set of Sublevel KPIs were, without more detailing, used to asked TD leader for their assessment of possible improvements. Improvements were given based on today's capacity, assuming that the overall system setup will permit the maximal achievable capacity. This approach worked only partly for the capacity assessment of IP2.
Regarding CCS, the **capacity** of the railway system cannot be raised by adding one system component alone. Only by having all changes incorporated in one system, the capacity can significantly be raised.
Overall, the TDs TD 2.1 (ATO), TD 2.3 (Moving block), TD2.4 (Train positioning), TD2.5 (Train integrity) and TD 2.8 (Virtual coupling) contribute to a capacity improvement.
Taking a high-level approach, deciding for the capacity of a track regarding CCS is how closely trains can follow each other. Looking at the list of TDs, the moving block technology will be a game changer (at least for high speed and regional lines which today usually have longer block sections), as it will allow trains to run very close together. So for this first model, we assume the improvement estimated for moving block (which can only be reached if the other systems also deliver) as deciding factor for the overall CCS attributed capacity change.

5.3.2.3. Sublevel KPIs for Capacity model contributed by IP3 (Infrastructure)

All TDs within IP3 have an impact on the **time needed for maintenance** (working time) of the infrastructure (except TD 3.10). Specifically, TDs 3.1 and 3.2 have an impact on the time for maintenance of switches & crossings, while TDs 3.3 and 3.4 are related to time for maintenance of tracks, TD 3.5 to bridges and tunnels, TD 3.9 to energy supply, TD 3.11 to passenger stations, and TDs 3.6, 3.7 and 3.8 are related to infrastructure management (and thus have an overarching effect on all infrastructure assets which is calculated after the impact from the other TDs).

Moreover, TDs 3.6-3.8 also have an impact on the **downtime for maintenance,** which thus include time to mobilise/demobilise the site and any extra time to take/give back track possessions.

TD 3.5 has an impact on the **axle load** allowed on bridges, which increases the freight train capacity (SPD4). This TD also has an impact on the **speed limitations for bridges and tunnels**, i.e. it decreases the transport time.

TD 3.11 has an impact on the **number of passenger departures and arrivals per station**.

5.3.2.4. Sublevel KPIs for Capacity model contributed by IP5 (Freight)

The train capacity is determined by the sublevel KPIs **train length**, **train weight** and **load factor**. The average train length and weight can be increased by means of longer trains or the coupling of short trains. The technology is developed within TD 5.4 “New freight propulsion system”. The KPI load factor is determined by an effective freight traffic management, developed within TD 5.2 “Digital transport management”.

5.3.3. Sublevel KPIs for Reliability & Punctuality model

As described in Chapter 5.2.3 measuring Reliability & Punctuality mainly means measuring delays. Besides external disturbances, which will not be influenced by the innovations of Shift2Rail, delays are mainly caused by two reasons: technical dysfunctions or process disturbances. The only exception is IT security breaches which are targeted in TD2.11 “Cyber security”.

Therefore, every technical part of the railway system covered by Shift2Rail (see also Chapter 5.4.1.), which will improve its technical reliability, will have a Sublevel KPI, which will be translatable into the **number of failures per year**. This applies for IP1, IP2, IP3 and IP5.

Further, some TDs will reduce process disturbances. The process disturbances improved by TDs of Shift2Rail are mainly caused due to **unavailable or delayed staff**. This aspect will especially be targeted by the TDs focussing on ATO and therefore be part of IP2 and IP5.

5.4. Development of KPI models

5.4.1. Subsystem structure

All Technical Demonstrators of Shift2Rail are part of the railway system. To take them correctly into account when creating the KPI models, a railway subsystem structure has to be build, which reflects the railway system in a structural way and covers all TDs which contribute to the key targets.
The railway system is therefore clustered in six modules, whereby the module 4 “IT-Systems” is not going to be directly been reflected in the models (for more information see Chapter 5.5.).

The model is therefore divided in the following five modules:

1. Passenger train*	2. Command & Control System	3. Infrastructure	5. Freight	6. Operation& Externalities
▪ Traction ▪ Control system ▪ Car body ▪ Running gear ▪ Brake ▪ Doors ▪ Interior ▪ Information system ▪ Others	▪ Communication ▪ ATO ▪ Moving block ▪ Train positioning ▪ Train integrity ▪ Test framework ▪ Standardisation ▪ Virtual coupling ▪ Traffic managem. ▪ Radio connection ▪ Cyber security	▪ Switches ▪ Track ▪ Bridges, tunnels & earth works ▪ Passenger stations ▪ Energy supply ▪ Infrastructure management ▪ Others	▪ Main line locomotive ▪ Waggons ▪ Marshalling yard ▪ Terminal	▪ Railway operation ▪ Externalities

Figure 2. Structure of the subsystem

Each module is covering several parts of the railway system. The modules and their parts are mostly identically with the Innovation Programmes (IP) and their TDs of Shift2Rail:

IP1, which is reflected by module 1 “Passenger train”, is divided in seven main components analysed and developed during Shift2Rail. Additionally, module 1 covers the parts “information (and entertainment) system” and “others”. “Others” includes all the equipment and system not covered by Shift2Rail developments but which are part of a train, for example HVAC systems. There will not be improvements over this concept during all Shift2Rail progress. The part “information (and entertainment) system” is an objective of IP4 in the Shift2Rail structure but as it is a part of the passenger train being covered in module 1.

IP2, which is reflected by module 2 “Command & Control System” is divided in eleven main components analysed and developed during Shift2Rail. For the first version of the models, it was decided to stick to this structure. Nevertheless, it has been already recognised that a division of CCS in its functional components is going to be more suitable than its current (technical) division, but this restructuring is going to be quite time-consuming and will therefore take place within WP4 of IMPACT-2.

IP3, which is reflected by module 3 “Infrastructure”, is divided in eleven TDs covering six main components analysed and developed during Shift2Rail. Additionally, module 3 covers the component “Others”. “Others” includes all the equipment and system not covered by Shift2Rail developments but which are part of the infrastructure, for example level crossings. There will not be improvements over this concept during all Shift2Rail progress. Further infrastructure parts especially dedicated to freight are part of module 5.

IP5, which is reflected by module 5 “Freight”, is divided in six TDs covering four main components and three management or operational concepts analysed and developed during Shift2Rail. Due to significant differences, the freight subsystem is divided into the assets: Main line locomotive, Freight waggons, Marshalling yard and Terminal. The operational concepts are covered in module 6.

Module 6 “Operation & Externalities” is not reflecting one specific IP of Shift2Rail, but covering issues of the operation of the trains, e. g. timetables, and externalities.

5.4.2. Structure of LCC model

5.4.2.1. LCC-Methodology

For the LCC model there have been four kinds of major cost elements identified: Capital Cost, Maintenance Cost, Dismantling Cost and Operational Cost. Thereby Capital Cost, Maintenance Cost and Dismantling Cost can be identified for every module and even for every part of the module of the railway system. Meanwhile Energy Cost and Labour Cost are going to be the two main areas, Shift2Rail is targeting, in the Operational Cost sector. Additionally, the topics Marshalling Yards and Terminals for freight are building an extra Operational Cost element. Therefore, the structure of the LCC model will be:

- Capital Cost:
  - Passenger Fleet Capital Cost
    - Traction Capital Cost
    - Control System Capital Cost
    - Carbody Capital Cost
    - Running Gear Capital Cost
    - Brakes Capital Cost
    - Doors Capital Cost
    - Interior Capital Cost
    - Information and Entertainment System Capital Cost
    - Others Capital Cost
  - CCS Capital Cost
    - Communication Capital Cost
    - ATO Capital Cost
    - Moving Block Capital Cost
    - Train Positioning Capital Cost
    - Train Integrity Capital Cost
    - Testing Capital Cost
    - Formal Methods Capital Cost
    - Coupling Capital Cost
    - Traffic Management Capital Cost
    - Smart Wayside Objects Capital Cost
    - IT Security Capital Cost
  - Infrastructure Capital Cost
    - Switches Capital Cost
    - Track Capital Cost
    - Bridges Tunnels Earthworks Capital Cost
    - Passenger Stations Capital Cost
    - Energy Supply Capital Cost
    - Further Assets Capital Cost
    - Infrastructure Managements Capital Cost
  - Freight Capital Cost
    - Loco Capital Cost
    - Waggon Capital Cost

- Maintenance Cost:
    - Passenger Fleet Maintenance Cost
        - Traction Maintenance Cost
        - Control System Maintenance Cost
        - Carbody Maintenance Cost
        - Running Gear Maintenance Cost
        - Brakes Maintenance Cost
        - Doors Maintenance Cost
        - Interior Maintenance Cost
        - Information and Entertainment System Maintenance Cost
        - Others Maintenance Cost
    - CCS Maintenance Cost
        - Communication Maintenance Cost
        - ATO Maintenance Cost
        - Moving Block Maintenance Cost
        - Train Positioning Maintenance Cost
        - Train Integrity Maintenance Cost
        - Formal Methods Maintenance Cost
        - Coupling Maintenance Cost
        - Traffic Management Maintenance Cost
        - Smart Wayside Objects Maintenance Cost
        - IT Security Maintenance Cost
    - Infrastructure Maintenance Cost
        - Switches Maintenance Cost
        - Track Maintenance Cost
        - Bridges Tunnels Earthworks Maintenance Cost
        - Passenger Stations Maintenance Cost
        - Energy Supply Maintenance Cost
        - Further Assets Maintenance Cost
        - Infrastructure Managements Maintenance Cost
    - Freight Maintenance Cost
        - Loco Maintenance Cost
        - Waggon Maintenance Cost

- Dismantling Cost:
  - Passenger Fleet Dismantling Cost
    - Traction Dismantling Cost
    - Control System Dismantling Cost
    - Carbody Dismantling Cost
    - Running Gear Dismantling Cost
    - Brakes Dismantling Cost
    - Doors Dismantling Cost
    - Interior Dismantling Cost
    - Information and Entertainment System Dismantling Cost
  - Locomotive Dismantling Cost
  - Freight Waggon Dismantling Cost
- Operational Passenger Service Cost:
  - Energy Cost
  - Labour Cost
- Operational Freight Service Cost:
  - Energy Cost
  - Labour Cost
  - Terminal Cost
    - Infrastructure Cost
    - Loading Cost
    - Staff Cost
    - Shunting Loco Cost
  - Marshalling yard Cost
    - Infrastructure Cost
    - Staff Cost
    - Energy Cost
    - Shunting Loco Cost

5.4.2.2. Conditions and Assumptions about LCC Methodology

As the structure shown above is reflecting a quite complex system, there are some conditions and assumptions, which apply to it:

- For infrastructure and CCS capital costs are understood as renewal cost. Therefore, dismantling costs are included in the calculations of capital cost for this parts of the railway system.
- Migration costs are not considered. This means today's costs are compared with future steady-state costs when the Shift2Rail innovations are already realised.
- Costs, which are not subject of Shift2Rail e.g. funding costs, are not included in the model.
- Incidents costs are not included in the LCC model.

- Fleet size is always bigger than service train fleet as maintenance, damages or inconveniences need to be considered. The functional open coupling enables coupling of different rolling stock types and TCMS versions, allowing grouping required fleet size and reducing the amount of required fleet.
- Energy consumption in the railway system by other users than the train (e. g. lighting in stations, operating a control centre etc.) is not considered in the energy cost in the first version of the model. Costs caused by energy losses through the energy distribution are not part of the energy cost (see also Chapter 5.5).

5.4.3. Structure of Capacity model

5.4.3.1. Capacity Methodology

In principle railway capacity is consisting of the capacity a train can carry and the number of trains the track can handle, including the ability of CCS for managing the trains. Another aspect, which is somehow related to both of these factors, is the number of coupled trains. These three aspects will define the overall Capacity model for passenger transport (SPD1, SPD2 and SPD3) as well as for freight transport (SPD4). But, because of the differences in the definition of Capacity (see Chapter 5.2.2.), i. e. passenger transport be measured for the peak hour as freight transport is going to be measured per day, especially the parts contributing to track capacity will differ. Nevertheless, the main capacity model structure will consist for all SPDs of:

- (wireless) Coupling ability
- Train capacity
- Track capacity

5.4.3.2. Conditions and Assumptions about Capacity Methodology

As the structure shown above is reflecting a quite complex system, there are some conditions and assumptions, which apply to it:

- Maintenance activities for infrastructure and CCS are not included in capacity of passenger transport, as capacity is calculated for the peak hours and maintenance activities both for train and track are done outside the timeframe.
- Train maintenance is not influencing in train capacity.
- Capacity of the signalling system is determined by moving block. The other TDs of IP2 are delivering required technology.
- Traction, running gear, braking, doors improvements increasing average speed or headway are not included in capacity model.

- Train capacity calculation is based on non-existing weight limitation. It is assumed that per component reduction, extra people could be added to train capacity. Usually, limitation is coming from volume more than from weight.
- Volume reduction of components increasing train capacity is not included in capacity calculation, because for this a way more detailed definition of the train profiles are needed.
- Doors improvements (passenger flow or faster opening and closing) related to dwell reduction are not included in capacity model.

5.4.4. Structure of Reliability & Punctuality model

5.4.4.1. Reliability & Punctuality Methodology

For the Reliability & Punctuality model, the number of delayed services in comparison to the number of all services is going to be crucial (see Chapter 5.2.3.). Failures in technical, functional or operational parts of the railway system (external factors are not considered here) are usually causing delayed services. Therefore, the Reliability & Punctuality model is going to estimate the number of delayed services by estimating the number of failures within the specific parts of the railway system. The structure of the model is therefore quite similar to the one of the LCC model. Only for this model parts of the freight transport module are integrated into the other modules. The Reliability & Punctuality model will be structured as follow:

- Train Service Disturbances
    - Traction Unavailability
    - TCMS Unavailability
    - Carbody Unavailability
    - Running Gear Unavailability
    - Brakes Unavailability
    - Doors Unavailability
    - Interiors Unavailability
    - Information and Entertainment Unavailability
    - Passenger Train Others Unavailability
    - Loco Unavailability
    - Waggon Unavailability

- CCS Service Disturbances
  - Communication System Unavailability
  - ATO Unavailability
  - Moving Block failures
  - Train Positioning failures
  - Train Integrity failures
  - Coupling failures
  - Smart Radio failures
  - IT Security breaches
- Infrastructure Service Disturbances
  - Switches Unavailability
  - Track Unavailability
  - Bridges Tunnels Earthworks Unavailability
  - Passenger Stations Unavailability
  - Energy Supply Unavailability
  - Further Assets Unavailability
  - Infrastructure Managements Unavailability
- Operational Service Disturbances
  - Staff Unavailability
  - TMS Unavailability
  - Terminal Unavailability
  - Yard Unavailability
  - Generic Disturbances

5.4.4.2. Conditions and Assumptions about Reliability & Punctuality Methodology

As the structure shown above is reflecting a quite complex system, there are some conditions and assumptions, which apply to it:

- Generic Disturbances consider all other operational or external disturbances, e.g. delayed train allocation, suicide, emergency doctor service, ….
- As of now, it is the assumption that every failure in one technical system of CCS will have an effect on the overall punctuality. When reworking the model to take a more functional approach, this will be verified in detail.

5.4.5. Interrelations

As in praxis all parts of the railway system interacting with each other, there can be interrelations between different parts of the system observed. These interactions need to be taken into account, when creating KPI models, reflecting the whole railway system. Nevertheless, modelling those interdependencies is very complex and will need a lot of cooperation between all affected TDs. Integrating these interrelations into the models will be very time-consuming and will be a major goal for WP4 of IMPACT-2.

Within the models there will be three levels on which interdependencies will occur: Within a module / IP, between modules / IPs or between different parts of the modules /IPs and between the key targets. Examples for these interdependencies are:

- Within a module / IP:
  - interoperability of main line locomotives and freight waggons
  - interactions between traction and brakes
  - almost all components of CCS interacting with each other
- Between modules / IPs or between different parts of the modules /IPs:
  - track maintenance cost reduction due to running gear improvements
  - traction, running gear, braking, doors improvements increasing average speed
- Between the key targets:
  - increase of train capacity (due to e.g. volume reduction of components) is influencing the LCC cost calculation (not taken into account so far)
  - increasing attractiveness (due to e. g. doors improvement effect (Autonomous PRM entrance)) is influencing the LCC cost calculation(not taken into account so far)
  - dwell time reduction (e. g. due to doors improvements) is influencing the LCC cost calculation (not taken into account so far

5.4.6. Input tables

Besides the challenge of further developing the model and shifting its qualitative nature into a quantitative model, there will be a lot of data needed to estimate the impact of the innovations developed within Shift2Rail on the key targets, Shift2Rail is aiming for.

To estimate the impact, the High level KPIs for defined scenarios will be first calculated at the current situation, meaning with technologies and operation of today´s (2013) state-of-the-art. Then the impacts of the TDs on single parts of the future will create changes of the current scenario, creating a future scenario. Then the High level KPIs for this future scenario, which include all innovations Shift2Rail is aiming for, can be calculated. The comparison of the High level KPIs of the current scenarios and the future scenarios will show the impact of the innovations of Shift2Rail on its key targets.

There will be three kinds of data needed to estimate the changes of the High level KPIs: reference scenario parameters, influence distribution and TD improvements.

Reference scenario parameters: The reference scenario parameters will create the current scenario. Some of the parameters will be important for the calculations (e.g. running km per year) and other will be for information purpose, so everyone involved will assume the same conditions (e.g. number of doors). The deliverable D4.1 "Reference scenario" [5] of IMPACT-1 is describing the concept of these reference scenario parameters in detail and is naming most of the parameters.

Influence distribution: As described previously, the model will have to merge the different components of the railway sector to calculate the High level KPIs. For merging the different parts of the modules and further merge the different modules with each other, there has to be a distribution of the influence a certain part of the system has on one parameter, e.g. when a train is delayed because of a technical failure at the train, how many times is it caused by the brakes, the traction, by the doors etc.

TD improvements: To get from the current scenario to the future scenario, the improvements of certain elements of the model, caused by the innovations of the different TDs, need to be implemented. These improvements will be put into effect on the level of the Sublevel KPIs. As those improvements will be created due to the results of the innovations researched within the TDs, the information about the magnitude of the improvements will have to come directly from the TDs. Parts of the model, which are not being improved by Shift2Rail (mainly called "others"; see Chapter 5.4.1.), will have no improvements.

5.4.7. Tool

To execute the KPI model different possibilities of tools are conceivable. To create a tool, which fits perfectly to the needs and expectations laid out with the KPI model, the Joint Undertaking has tendered the creation of a customised tool for the developed KPI model. It was foreseen that this tool was going to be developed in parallel to the KPI modelling, but because of circumstances, which were not within the scope of IMPACT-1, this development has been postponed.

Therefore, the first rough model including calculations and values developed in IMPACT-2 is going to be created via an Excel table. For the discussions and assessments of the Sublevel KPIs with the leaders of the TDs, drawings in PowerPoint have been used. PowerPoint drawings were also used to show the subsystem structure of the model.

5.5. Model limitations

All aspects of noise reduction, e.g. capacity increase because of enabling night services or urban operation, are not included yet.

Energy Usage is going to be provided by FINE1 project. The KPI model will not include the calculation of the Energy Usage, but only the result. Further, energy losses in distribution are not considered in the model. It will have to be clarified, in which way energy losses can be matched with the information provided by FINE1.

As for IP4, at this stage, its improvements of the railway system are not yet included in the KPI Model of the three quantified KPIs. Hence, for IP4 a dedicated approach to model the impact of IT tools on the passengers' modal choice is requested. Due to its particularities, this tailored-made approach will be developed within the scope of IMPACT-2. WP4 relies on the following inputs: Passenger Demand Forecasting Handbook, National Passenger Satisfaction Survey and an approach increasing attractiveness in a sense of reducing obstacles. Increasing of attractiveness due to improvements within IP1, IP2, IP3 or IP5, which are not caused by reduction of cost or increasing of capacity or reliability and punctuality, need then also be depicted in the model.

6. Conclusions

In this deliverable the qualitative model developed within IMPACT-1 has been described. This model covers all main impacts of the innovations developed in Shift2Rail trough the Technical Demonstrators, which do have a measurable influence on the key targets of Shift2Rail.
The definition of the key targets (Chapter 5.2.) as well as the interface to the TDs (Chapter 5.3.) has been described. Within IMPACT-2 the interface to the TDs will be further developed, where applicable.
Finally, the general structure of the KPI model has been developed (Chapter 5.4.). This first qualitative KPI model was done taking into account several assumptions, conditions and limitations. Therefore, in WP4 of IMPACT-2 besides transferring the qualitative model into a quantitative model, reducing the assumptions, conditions and limitations is a major task.

7. References

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8. Appendices

No appendices attached.