11 The KPI-Model – An integrated KPI assessment methodology to estimate the impact of different innovations in the railway sector

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11.1 Abstract

The Shift2Rail Joint Undertaking (S2R) has set impact targets for the future rail system. Those targets of the KPIs, calculated by comparing future KPIs in the year 2030 to baseline KPIs as of 2013, are defined in the Shift2Rail Master Plan. These include among others to double the capacity (+100%), half the life cycle costs (LCC) (-50%) and to increase punctuality by improving reliability by 50% [1]. In order to keep track of the realisation of these targets and to measure their degree of fulfilment a quantitative KPI model has been developed. The modelling approach and implementation are discussed in this contribution.

11.2 Introduction

As part of the cross-cutting activities of the Shift2Rail Joint Undertaking (S2R), the IMPACT-2 project focuses, inter alia, on the integrated assessment of the impacts of the S2R innovations by developing a Key Performance Indicator (KPI) methodology. Based on the S2R objectives, not only the economic impacts of the S2R innovations but also the socio-economic and modal shift impacts were analyzed within the framework of Work Area 2 of the Project IMPACT-2. As shown in Figure 11-1, three models were created for this purpose: the KPI model (in orange), the Customer Experience Model (in grey) and the Modal Shift Model (in green).
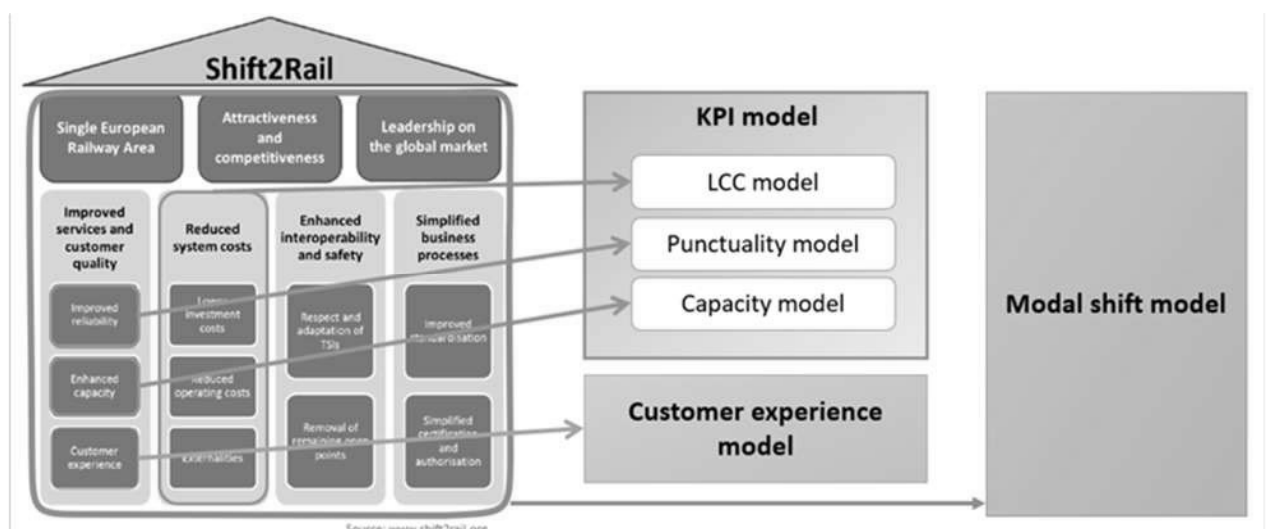

Figure 11-1: Overview of the different IMPACT-2 models of Shift2Rail including the KPI model

The KPI model estimates the impacts of the S2R innovations on the future railway system once the S2R innovations are implemented. The KPIs considered within the KPI model are Life-Cycle-Cost (LCC), Reliability & Punctuality, and Capacity. The targets of the KPIs, calculated by comparing future KPIs (2030) to baseline KPIs (2013), are defined in the Shift2Rail Master Plan [1] as follows:

- doubling Capacity (+100%);

- halving Life-Cycle-Cost (-50%);

- increasing Punctuality by improving reliability by +50%

The KPI Model is a quantitative model organized into three sub-models: LCC Model, Punctuality Model and Capacity Model. It is based on specific generic scenarios called System Platform Demonstrators (SPD), which are structured into four market segments: High Speed, Regional, Urban (metro) and Freight. Besides the KPI Model, the Customer Experience Model specifically identifies areas with high potential for improvement in terms of customer satisfaction. Finally, the Modal Shift Model was developed to reflect the impact of the S2R innovations on modal shift. The focus of this paper is on the KPI model.

11.3 Methodology

11.3.1   Common Approach

The KPI model developed in IMPACT-2 is based on the general structure of the KPI model, developed in IMPACT-1 [6]. The developed KPI model is based on S2R's five key Innovation Programmes (IPs) encompassing relevant technical and functional technology subsystems as structured in Rolling Stock (IP1), Command, Control and Signaling (IP2), Optimized Infrastructure (IP3), Digital Services (IP4) and Rail Freight (IP5) [7].

The three separated sub-models display the effects of S2R-innovations on the KPIs Life-Cycle Costs (LCC), Reliability & Punctuality (or simply Punctuality in what follows) and Capacity. Thereby the sub-models have been developed separately for passenger transport and for freight transport. For freight, the model is further split into three sub-scenarios (i.e., single wagon train, block train and combined transport train) to better capture the operational differences. Hence, there are in total six sub-models. Similar modelling approaches and algorithmics have been used for all of them. Figure 11-2 demonstrates the common approach of the KPI methodology.
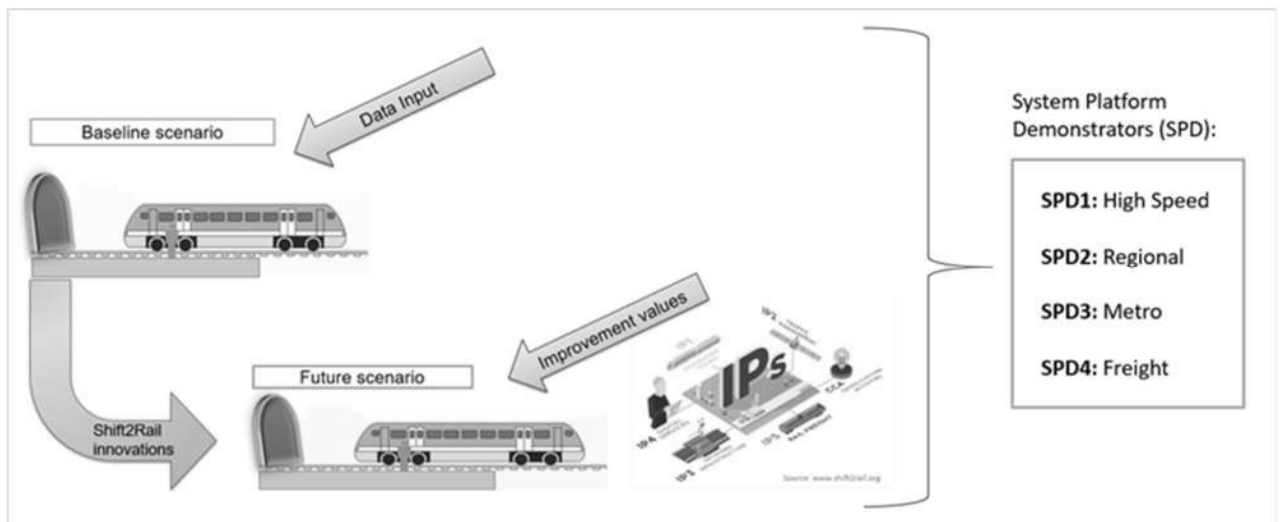
Figure 11-2: Illustration of the adopted methodological approach in the KPI model of IMPACT-2

The KPI model generates in the first step a baseline scenario describing a defined representative scenario for the European railway system. In the second step, the effects of the S2R innovations are analyzed within the IPs by their so-called Technical Demonstrators (TDs) in terms of the expected impacts on the three KPIs. This leads to percentage improvements, hereafter called "improvement values". The targets are the maximum achievable improvements as a priority for the respective KPI. The improvement values are then fed into the KPI model. Finally, calculating a scenario for a future railway system in which the roll out of all S2R innovations is completed. In the following, the three high-level KPIs are described first for the passenger and then for the freight model.

11.3.2 Passenger Specific Model

The methodology for estimating improvements in LCC is based on the assessment of system components existing in the baseline scenario as well as in a modified or improved form in the future Shift2Rail scenario [4]. Figure 11-3 provides an overview of the LCC model structure.
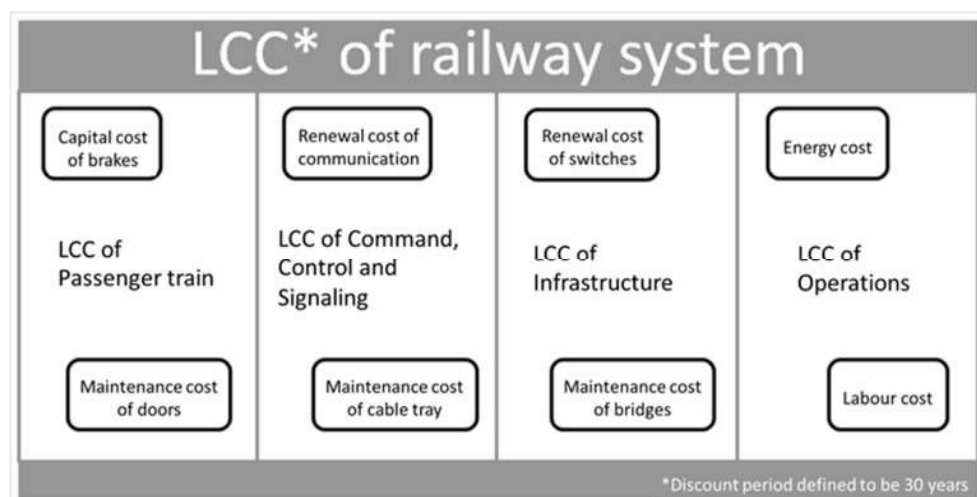

Figure 11-3: Structure of the passenger specific LCC model of Shift2Rail

In the baseline scenario, both the capital costs and the operational costs of various system components were collected and discounted over a period of 30 years. For the future scenario, the TDs in IP1 (Rolling Stock) and in IP3 (Infrastructure) provided specific improvement values on both capital and operational costs resulting from the technological development of the system components. For the innovations of Command, Control and Signaling (CCS), an additional approach was integrated into the LCC model. This approach was necessary as most system components would be replaced or changed in such a way that a cost improvement of the future system could not be assigned directly to each individual component. Several improvements depend on the system effect or aim at transferring functions to other components (e.g., more functions on the train instead of the infrastructure). For this reason, the methodology was extended to allow the estimation of LCC improvements through Command, Control and Signaling innovations by allocating the components of the reference system and the future Shift2Rail to the functions for which they are required [4].

The methodology for assessing capacity improvements is based on peak hours. The Capacity calculation consists of three main parts: First, the track capacity is defined as the number of trains per peak hour per day. Second, Train Capacity is defined as the number of passengers that can potentially be transported per peak hour on a given route. Last, coupling ability is defined as the number of, coupled units per train. Hence, the capacity model is composed of the capacity improvements of the infrastructure, of the trains and of the signaling system [4].

The methodology for assessing punctuality improvements is applicable in cases where the technical innovations provide a higher reliability or a shorter recovery from delays.
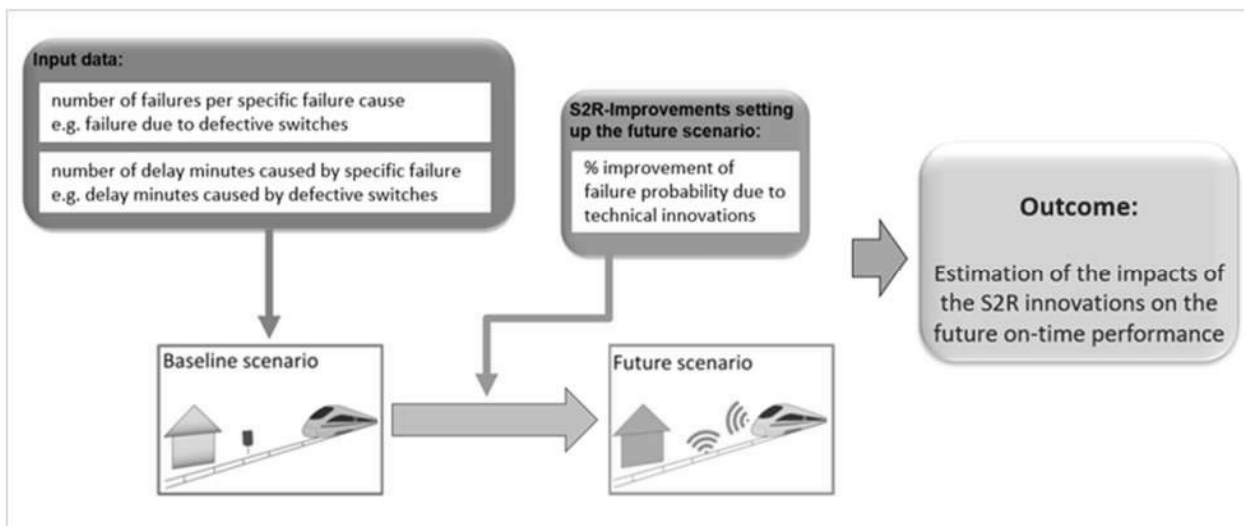

Figure 11-4: Implementation of the methodology into the punctuality model of Shift2Rail

The methodology enables an estimation of the punctuality improvement achieved by the reduction of delay minutes due to a decrease in the number of failures resulting from technical developments. For the baseline scenario, we used input data that was provided by the railway undertakings and infrastructure managers which were actively involved in S2R. In general, the data shows the annual number of failures per specific cause of failure, e.g., the annual number of failures due to defective switches, as well as the number of average delay minutes caused by specific failures, e.g., delay minutes due to defective switches. Based on the input data for the baseline scenario and the improvement values provided by the TDs for the future scenario,

we develop a punctuality model to estimate the impacts of the S2R innovations on the future on-time performance. In addition, special calculation methods were used for parameters that did not fit into the general methodology, i.e., the Train Management System (TMS). In this case, a general performance improvement of the railway system due to an improved handling of delay scenarios has been integrated into the punctuality model [5].

The specific formulas of the KPI model as well as its detailed data are under confidentiality. Consequently, these formulas cannot be further enclosed in this paper.

11.3.3   Freight Specific Model

The model for freight transport is more complex than for passenger transport. First of all, three different freight transport categories are considered: single wagon, block, and intermodal transport. Secondly, the total freight transport process from terminal is considered. Figure 11-5 illustrates the freight transport process for the single wagon category.
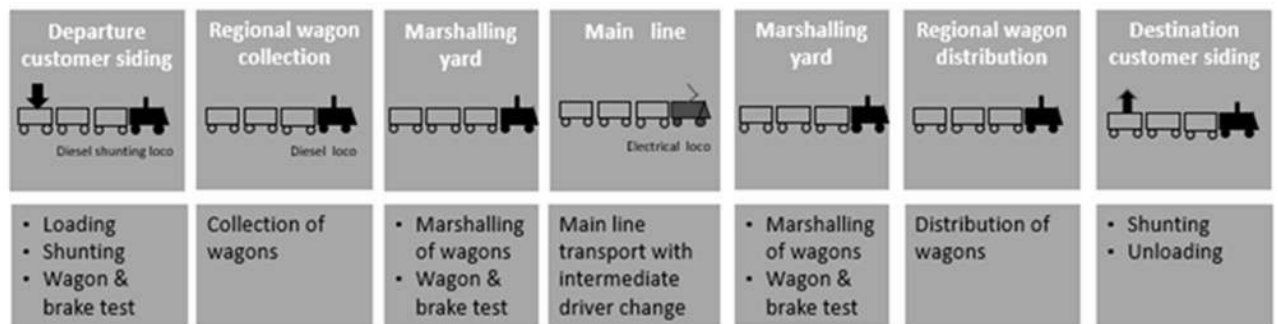

Figure 11-5: Illustration of the freight transport process for single wagon category

The consequence for the LCC- and punctuality model is that beside trains, infrastructure and CCS, additional assets are considered such as terminals and yards. Furthermore, the trains are split into locomotives and wagons since they are decoupled in terminals and yards. Due to the complex process, operational delays and costs play an important role.

It must be considered that Shift2Rail innovations in the freight transport not only have an impact on the assets itself but also on the freight process time. Due to the digitalisation of the freight process including automatic coupling, the process time is significantly reduced. This has a direct impact on the utilisation of the locomotives and wagons (increased yearly km). Hence, the process time has to be calculated in a separate model. Therefore, LCC-reduction is possible although the capital costs of the locomotives and wagons increase.

The capacity model considers two different freight innovations:

- Longer freight trains and coupled trains

- Wagons with increased load per train length

Both innovations also reduce the LCC per ton since more load or containers can be transported with one train.

The last difference to the passenger model is energy consumption and costs. They are influenced by different innovations:

- Improved wagon aerodynamics

- Increased speed

- Connected driver assistant system

Therefore, special energy simulations must be carried out to determine the changes in energy consumption.

11.4 Results

The KPI model was developed using Microsoft spreadsheet software Excel. Through the use of Microsoft Excel, it was possible to collect all the information in one file, keeping the input data, general information, calculations and results on separate sheets [4]. It had the additional advantage that all companies in WP4 had a license and the necessary skills to work with the program. Figure 11-6 shows the elements of the KPI Model in Excel.

Sheet 4: InputParameters
Sheet 5: Distribution
Sheet 6: Improvements
Sheet 7: Accuracy levels

Sheet 9: LCCSubsystem
Sheet 12: LCCSubsystem_Freight

Sheet 10: PunctualitySubsystem
Sheet 13: PunctualitySubsystem_Freight

Sheet 11: Capacity_Subsystem
Sheet 14: Capacity_Freight

Sheet 8: Overview

Sheet 1: Cover & History
Sheet 2: SPDParameters
Sheet 3: Decisions
Sheet 15: Sources
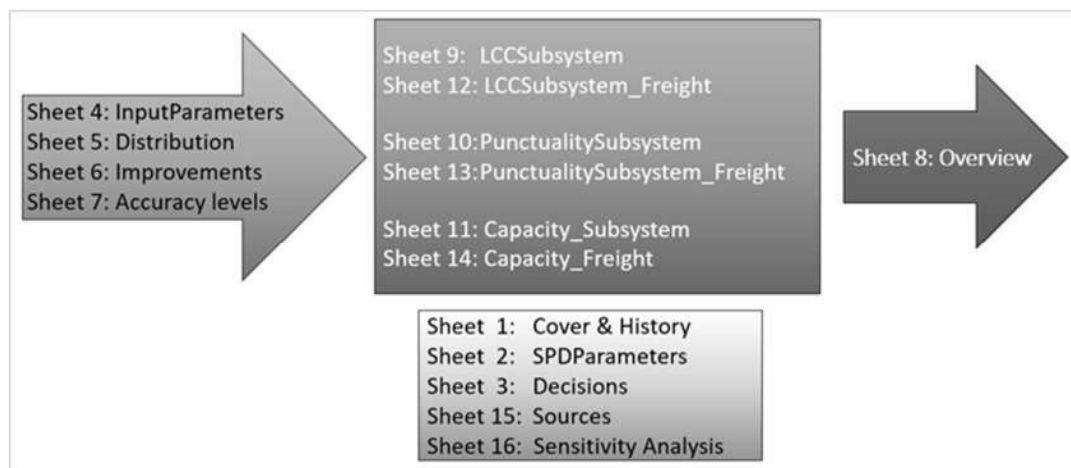Sheet 16: Sensitivity Analysis

Figure 11-6: Elements of the KPI Excel Model in Shift2Rail

The KPI Model is made up of several sheets feeding into each other. Information on the input parameters for the respective SPDs are entered in the input sheets (in yellow in Figure 11-6). The input information is structured in four input sheets as follows [4]:

- Input Parameters: In this sheet, data is collected to describe the baseline scenario for all four SPDs.

- Distribution: In this sheet, a percentage share of total values is determined for innovations where cost, capacity or punctuality data cannot be captured at the level of detail at which the individual TDs work, e.g., the costs or weights of individual train components are often not available for each component, but only for the train as a whole.

- Improvements: The percentage improvement values provided by the TDs are collected in this sheet.

- <u>Accuracy levels</u>: This is understood as the level of precision under which the TDs have delivered their improvement values.

With the input data, the KPI model creates in a second step the six individual sub-models (in red in Figure 11-6). These Model sheets and its calculations are as follows [4]:

- LCC model related to passenger railway service

- LCC model related to freight railway service

- Capacity related to passenger railway service

- Capacity related to freight railway service

- Punctuality related to passenger railway service

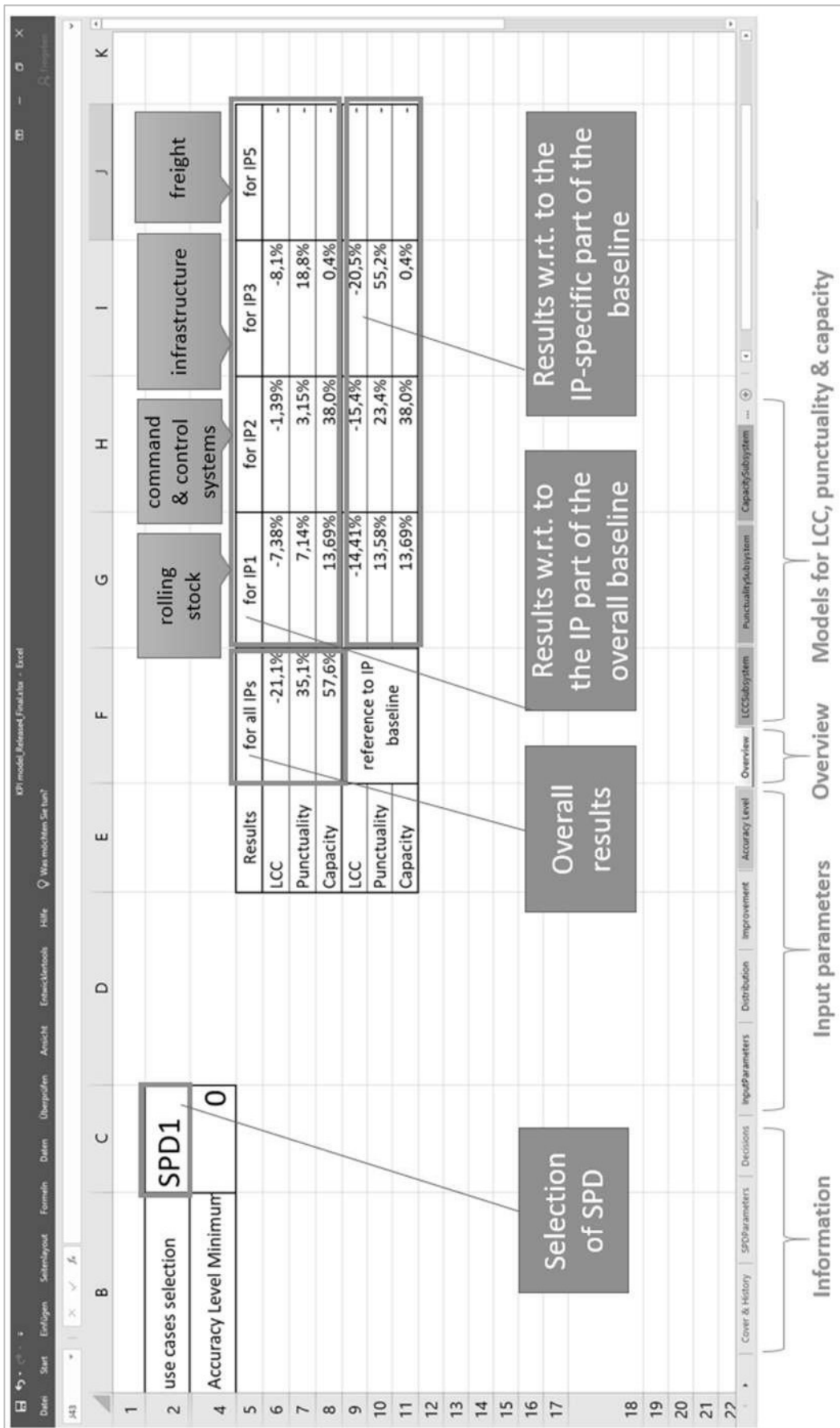- Punctuality related to freight railway service

Figure 11-7: Internal structure of the presentation of the assessment results in the KPI Model of Shift2Rail

In the Model sheets, the baseline scenario as well as the future scenarios including the technical innovations are calculated.

For a better summary, the results of the KPI assessment are shown in the result-sheet named "Overview" (in blue in Figure 11-6). Otherwise, there are further administrative or informative sheets (in grey in Figure 11-6) that supply information on the cover and history, explanations, decisions, sources and SPD parameters. Finally, the results of the integrated KPI assessment are displayed in the "Overview" sheet, see Figure 11-7.

On the Overview sheet, it is possible with the help of a drop-down list to select the required SPD. After selecting the respective SPD, the spreadsheet calculates the results of the S2R innovations on the respective high-level KPIs LCC, Punctuality and Capacity. Within this spreadsheet the improvements to the KPIs for the overall results are calculated, meaning when all S2R innovations have been implemented. Further, the spreadsheet provides the results with regards to the IP part of the overall baseline. And finally, the results in relation to the IP-specific part of the baseline are calculated in the model. The impacts of the IPs' technologies are measured separately in this case. As shown, IP1, IP2, IP3 and IP5 are included in the KPI model. Nevertheless, IP4 is considered within the customer experience model, which is mainly about removing obstacles for passengers, thus estimating innovation's potential to improve the customer experience.

11.5 Discussion and conclusion

With the described approach, a powerful tool for the impact estimation of the technical developments in the Shift2Rail project has been developed. Given the way the model is structured, it is possible to adapt it to other comprehensive assessments in the railway system. When the necessary data is available, the parameters used in the input sheets can be applied to other use cases. The general calculations, that are used for the three high-level KPIs in the six model sheets, are written in such a way that they calculate the results for any changes in the input sheets. There are, however, a number of special calculatory approaches that are included as described in chapter 2.2 and 2.3. These are necessary due to the high complexity of the railway system. This does, however, have the effect that these calculations cannot easily be transferred to other use cases as they are specifically designed for the project requirements of Shift2Rail.

11.6 References

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11.7 Acknowledgements

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