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Impact of Shift2Rail - a KPI model for the entire railway system

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Abstract

The Joint Undertaking Shift2Rail comprises five Innovation Programs and five Cross Cutting Activities of European railway research and development within the next years. More than 40 Technical Demonstrators will be developed in the field of rolling stock, traffic management and control systems, infrastructure, IT solutions and rail freight. A technology and impact evaluation is an essential element within the Shift2Rail Joint Undertaking in order to show the effect that this initiative will have on its key target KPIs: to double the capacity and availability and to reduce the costs of the railway system by 50%. The Project "IMPACT-1" is producing a comprehensive bottom-up KPI model with the aim to show the interdependencies between the technological or procedural developments and the high level KPIs of the railway system. The overall objective is to prove the achievement of the objectives of Shift2Rail by determining to which extent the aims of reducing costs and improving availability and capacity will be reached. In a first step, these interdependencies will be analyzed as cause-and-effect chains in order to obtain a qualitative model. Subsequently, the qualitative relations will be replaced by mathematical and logical descriptions. This is necessary in order to apply the model to data of the different market segments like high speed, regional, urban / suburban and freight rail. The analysis of the interdependencies as well as the application of the model is done in close collaboration between industry, infrastructure managers, railway operators and scientific institutions. Thus a KPI model will be generated which covers all aspects of the entire railway system. The presentation will cover the approach that has been chosen to develop the qualitative and quantitative model, share the experience made during this process and show the first results of the impact assessment of the Joint Undertaking Shift2Rail.

Keywords: Railway Technology; Impact Assessment; Cause-and-Effect Chains, Shift2Rail

Nomenclature

CCA	Cross-Cutting Activities (of Shift2Rail)
IP	Innovation Program (of Shift2Rail)
KPI	Key Performance Indicator
LCC	Life Cycle Cost
SPD	System Platform Demonstrator
TD	Technical Demonstrator (of Shift2Rail)
WA	Work Area (of Shift2Rail)

1. Introduction

Many new ideas are understood as "innovations". But: There is an important step from invention to innovation. An invention becomes an innovation as soon as it is used – typically, but not necessarily, in an economic or industrial way. The resulting question is: How can we estimate the economic impact of an invention as soon as it becomes an innovation. If this impact is too low it is quite probable that it never will become an innovation. The higher the impact is the higher becomes the probability that this will happen.

In industrial and economic environments it is state of the art to measure the performance of services, systems or organisations by so called Key Performance Indicators (KPI) [Parmenter2015]. Those parameters could be absolute values or relative values, i.e. a percentage against a well-defined baseline as 100%. Initially this approach was foreseen to estimate the operational performance, but it can be applied on everything what has an impact on the operation. On the other hand, it needs to be applied on an existing application or a similarly detailed generic case. This should be explained on some examples: Typical KPIs for a railway could be:

- Number of Trains delayed for more than 5 Minutes at one day
- Percentage of cancelled trains in one week
- Operational cost per passenger and Kilometre
- Etc.

Typically the KPI reflect parameters with economic relevance, which should be optimized.

In the next step, it could be tried to estimate the effect of an innovation on the KPI. So if e.g. 25% of the delays more than 5 Minutes are caused by disturbed point machines the use of an innovative type with a higher reliability could lead to a better punctuality KPI.

It is a standard requirement in projects under the Horizon 2020 program of the European Commission to estimate the impact of the results of the projects. In the following contribution it should be discussed how the concept of KPI can be applied to the results of the research projects in the context of the Shift2Rail Joint Undertaking.

2. Context: The Shift2Rail Joint Undertaking

The European research for Railways will be done for the next coming years mainly in the Shift2Rail Joint Undertaking. The European Union, two railways and six industry members founded the Joint Undertaking. It comprises five so-called Innovation Programs (IP) and six Work Areas (WA) of Cross Cutting Activities (CCA) of railway research and development for the near future. More than 40 Technical Demonstrators (TD) will be developed in the field of rolling stock, traffic management and control systems, infrastructure, IT solutions and rail freight [Shift2Rail2015]. The Fig. 1 shows the five IPs of Shift2Rail.

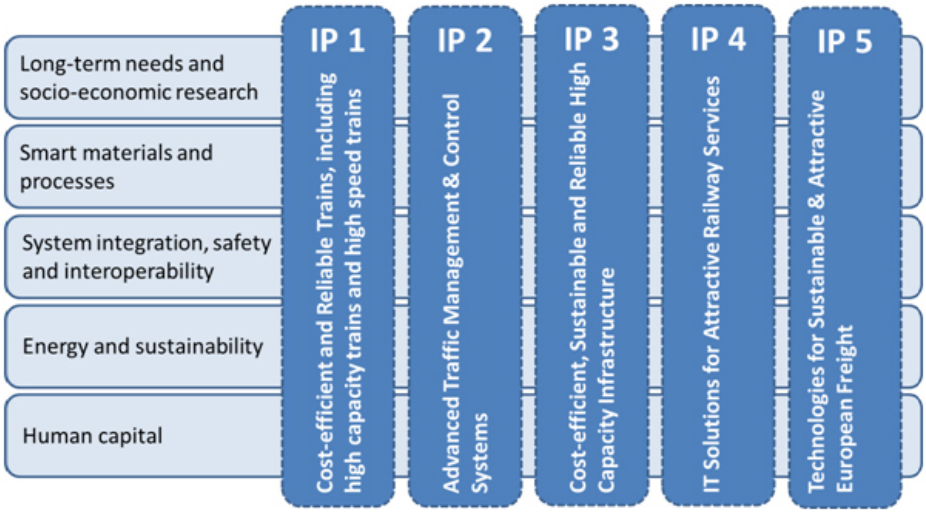

Fig. 1: The five IPs of Shift2Rail [Shift2Rail2015]

The six work areas of the CCA are shown in Fig. 2.

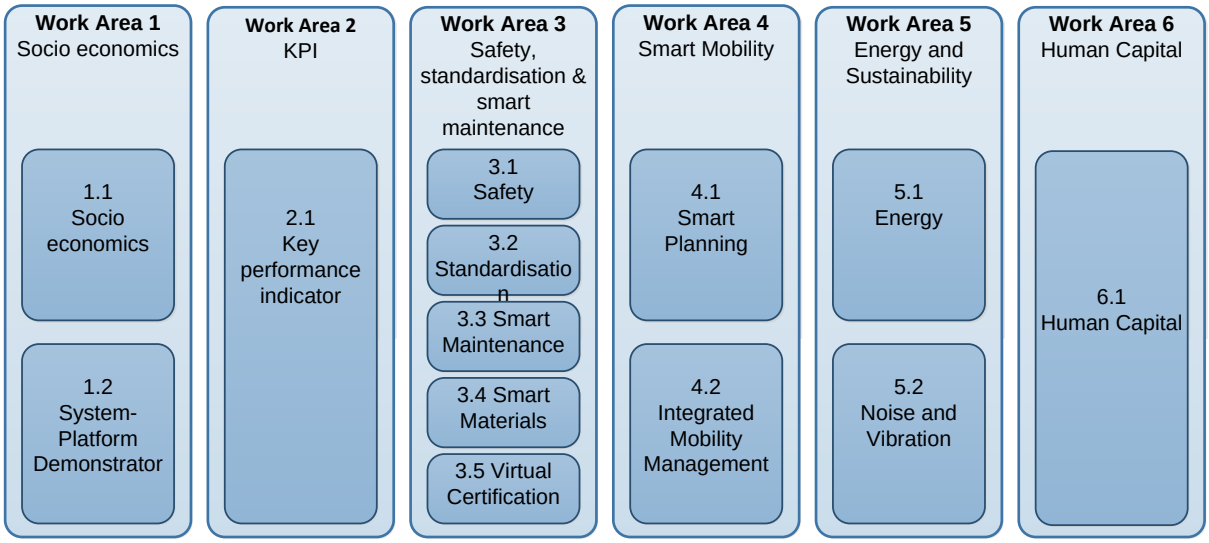

Fig. 2: The six WA of the CCA of Shift2Rail

3. Approach and Methodology

The overall effects of the Shift2Rail initiative on the whole railway system will be quantified for three main (high-level) target KPIs: a) the overall costs of the railway system, b) the capacity and c) the reliability of the railway system in terms of punctuality. These parameters are the top level KPIs which will be influenced by the technical demonstrators of Shift2Rail, where all technical and process-related innovations are developed.

The approach is basically divided into two steps: in the first phase, a qualitative analysis of the effects of each TD on the main KPIs will be performed. In the second phase, the qualitative model will be complemented with mathematical descriptions or weighting factors for the effects. The model will then be filled with data from the TDs in order to quantify the effects of Shift2Rail.

Since the initiative aims at increasing the share of the railway of the modal split, the parameter “attractiveness” for the passengers and freight transport buyers is monitored and displayed as well, however without being quantified.

The qualitative analysis is done by building cause-and-effect chains between the technical details that are being developed and their influence on more aggregated components or processes of the railway system. System expertise of the companies involved in Shift2Rail will ensure that the technical or process-related measures are taken into account in the correct manner. By bringing together the different cause-and-effect-chains to a logical model, the parameters will be further integrated to higher aggregation levels, ending at the top level KPIs. Logical and functional interconnections between the effects of complementary developments have to be identified and represented in the model as well. Thus, a KPI model for the entire railway system will be developed.

One simple example for such cause-and-effect chain could be: the technical demonstrator "running gear", see Fig. 3, deals amongst others with the design of the bogie. One improvement of this will be the reduction of weight for the running gear of the car. This effect will have an influence on the energy consumption of the single car and therefore on the whole train. This will reduce the costs for operating the whole train fleet. Another interpretation of the reduced weight of the running gear could be to increase the payload of the car, the train and the fleet in order to increase the revenues that could be gained by the train operator. Of course this is only one obvious result of developing a new bogie. There will be many more effects of this technical demonstrator like wear-resistant construction, improved driving dynamics etc. which also will be considered. And this is only one of more than 40 technical demonstrators of the Shift2Rail initiative.

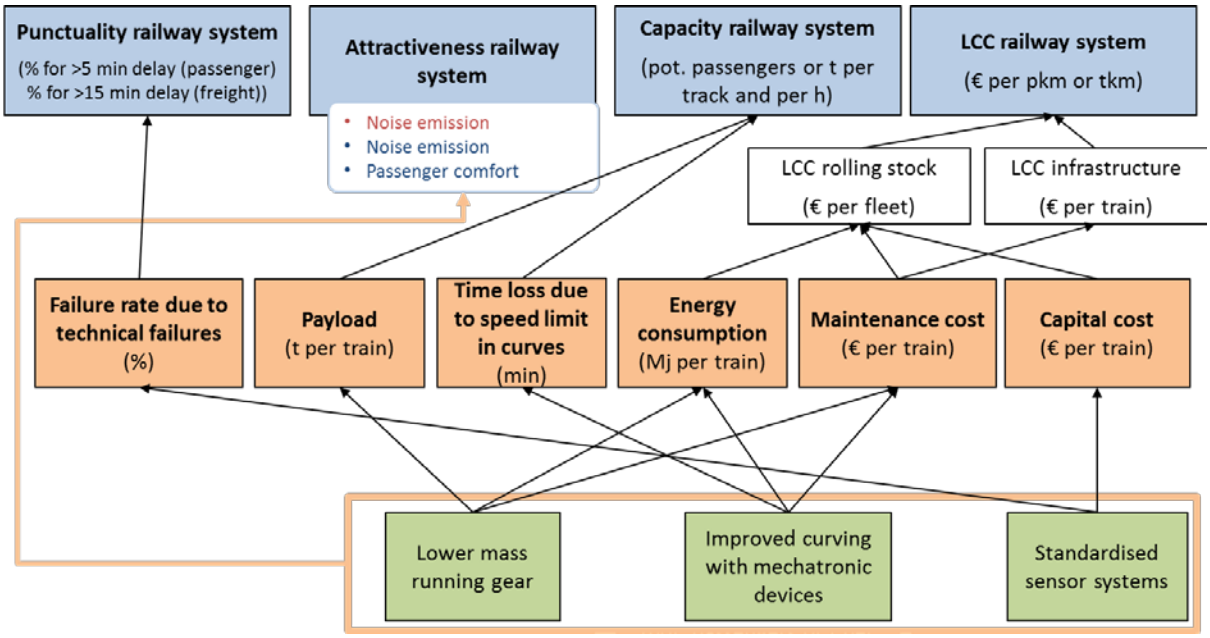

Fig. 3: Example of a KPI model for running gear development (working status)

As a further example on the KPI chain, the contributions of track development to the railway system high-level KPIs are illustrated in Fig. 4. At the lowest KPI level, the green boxes indicate four key improvements of the tracks foreseen in the Shift2Rail research program. Here "Improved design" mainly refers to when the track is built whereas the other three parameters are linked to the operation of the track. The four low-level KPIs are then linked to five intermediate level KPIs shown in orange boxes. For instance "Capital cost", expressed in Euro per track-km, covers the track investment cost from a life cycle cost (LCC) perspective considering the expected lifetime and interest rate. "Maintenance cost" includes maintenance and renewal costs for the track and is related to the traffic volume in terms of gross ton-km. The five orange boxes are then connected to four high-level KPIs in blue boxes. Note that for "LCC railway system" the track LCC is related to traffic volume the track hosts in terms of passenger-km and net ton-km. "Capacity" and "Punctuality" are here related to time needed for track-related maintenance and correction of possible failures. Note that "Time needed for maintenance" does not only

depend on how extensive the maintenance action is, but also how efficiently it is carried out and to some extent on the track design. "Attractiveness railway system" here covers service levels to the train operators, noise emission to nearby residents, safety of track workers and sustainability to the society and environment.

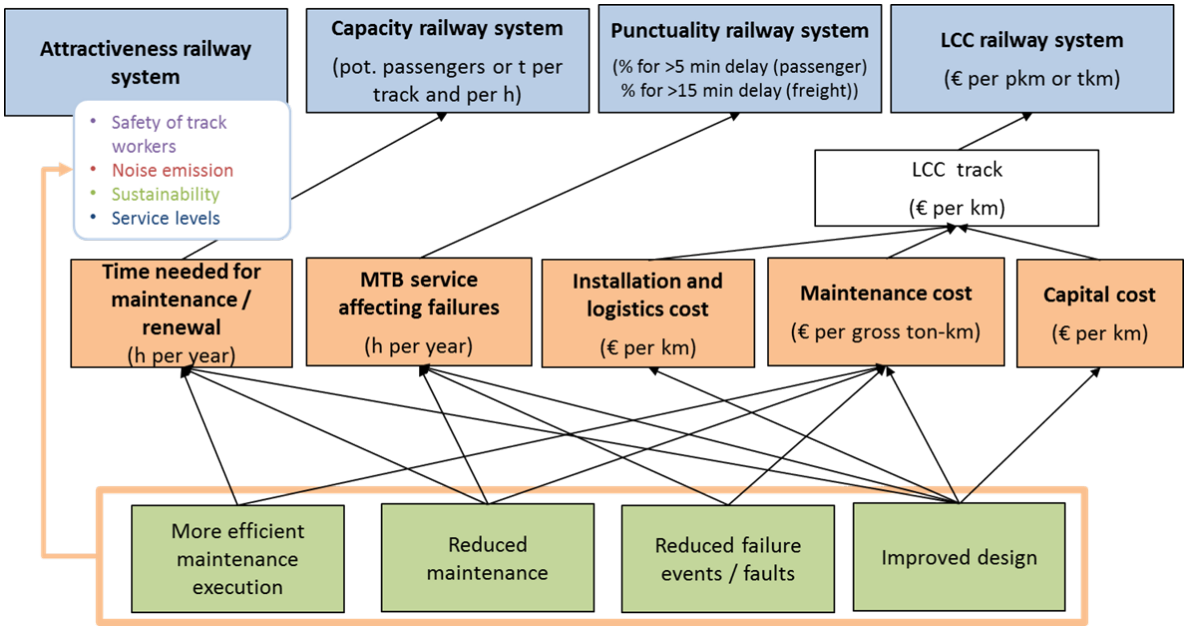

Fig. 4: Example of a KPI model for track development (working status)

Once the qualitative analysis is completed, the quantitative analysis will be performed by assessing the amount of effect that each of the parameters at the lowest level of the model will have and the share which all model parameters have on the respective next higher level. This is a challenging task which relies to a large extent on the expertise of the different railway, industry and scientific experts that are represented in Shift2Rail who will review and validate the different parts and aspects of the model.

In order to display the overall result of Shift2Rail, the quantitative railway model needs to be filled with specific data in order to see the improvements of the KPIs in comparison to the previous status, i.e. the baseline for the comparison. Therefore transfer parameters are defined at a certain level of detail which will be fed by each Technology Demonstrator in order to ensure that the expertise within the TDs will be incorporated in the assessment. Since the investigation comprises a cost reduction analysis, sensitive data might be addressed that may not be revealed to third persons. This may also apply for certain technical solutions. In this case, percentaged improvements will be estimated by the experts.

4. System Platform Demonstrators

The effects that can be achieved by Shift2Rail always need to be determined for a specific scenario in order to have data to compare. The methodology of Shift2Rail comprises a distinction between the railway market segments "high speed", "regional", "urban / suburban" and "freight". Based on this segmentation, four so-called "system platform demonstrators" (SPD) will be defined in order to demonstrate the bundle of developments of Shift2Rail that can be applied. The definition of each SPD includes a specific line or sub-network, specific rolling stock, infrastructure and signaling equipment as well as an operating program. The global concept is shown in Fig. 5.

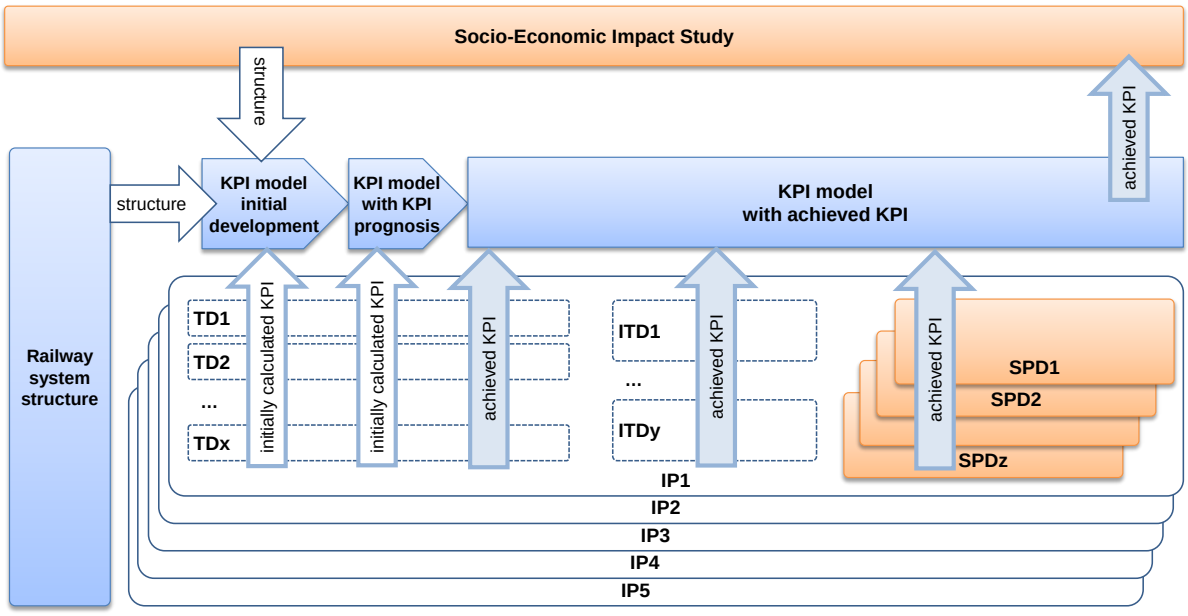

Fig. 5: General Concept of the KPI estimation using the SPD

The SPD are fictitious scenarios. They are based on existing real world networks, timetables etc., but will be complemented by additional artificial amendments and assumptions as required in order to represent the Shift2Rail activities. E.g. a line without bridges or tunnels will not be able to show improvements from the Technical Demonstrator “Bridges & Tunnels”, therefore such elements have to be contained in the SPDs.

An existing line instead of a purely fictitious example has the big advantage that real data for the line parameters or infrastructure description can be used. However, components like the running stock, speed profiles, signaling system or other technology installed etc. can vary from the real world example in order to make the SPD as generic and representative as possible for the Shift2Rail demonstration purpose.

The KPI model will be applied to each of the SPDs once for the baseline scenario and for the future scenario. The baseline scenario will consist of the technology in place before the Shift2Rail developments had started. The future scenario assumes that all effects that Shift2Rail will cause are taken into account.
This will show the difference between the actual status and the railway system after Shift2Rail. By comparing these figures, the interconnections of the inventions of Shift2Rail on the overall costs, the capacity and the reliability across the whole railway system and for the different market segments will be displayed. The comparison of these two scenarios per SPD will demonstrate the effectiveness of the overall initiative.

Not each of the five Shift2Rail Innovation Programs needs to be represented in each SPD. Table 1 shows the matrix displaying the allocation of IPs and SPDs.

Table 1. Allocation of IP and SPD.

System Platform Demonstrators	IP1	IP2	IP3	IP4	IP5
SPD 1: High Speed	X	X	X	X	
SPD 2: Urban/Suburban	X	X	X	X	
SPD 3: Regional	X	X	X	X	
SPD 4: Freight		X	X		X

E.g. the SPD “Regional” will be used as demonstrator of the results of IP1 “Rolling Stock”, IP2 “Signalling”, IP3 “Infrastructure” and IP4 “IT-Solutions” in a regional line context. Therefore typical parameters for this kind of market segment were chosen: The maximum speed of this line is 160 km/h with intermittent train protection

and axle counters. The line length is about 250km with a distance between stations of 10-25 km. Up to 8 trains are running per direction in the peak hour. The trains are EMU with single deck cars and a length of 70m. For the actual calculation, a detailed data base with the necessary parameters will be used, containing the relevant technical specifications of train, infrastructure and signaling system.

5. Conclusion and Perspective

5.1. Conclusion

The concept of the Key Performance Indicators has been applied to estimate the impact of the innovations to be developed in the Shift2Rail projects. A complex model of the results and interactions of the TDs is currently under development. Four generic application scenarios have been defined in so-called System Platform Demonstrators for high speed, regional and urban/sub-urban for passenger transport as well as for freight as fourth SPD. Currently the model is under development and the relevant parameters for reference trains, infrastructures and signaling layout will be identified.

5.2. Perspective

During the further development of Shift2Rail the models will be further developed and refined. One activity is planned to evaluate the models by using existing data from real railways to fine-tune the models. Finally the SPDs are to be checked with respect to coherence of the assumptions. When all this activities will be finalized a powerful tool for the estimation of innovations impacts will be developed and validated. This can be used in the future for any technology impacting the railway system.

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