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A framework to assess innovative railway technologies' impact on mode choice

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Abstract

Within the Shift2Rail project IMPACT-2 a model framework is developed to assess the impact of railway innovations on modal split. The railway innovations are evaluated in a KPI model and a customer experience model. Effects on Life-Cycle-Cost (LCC), Capacity and Reliability & Punctuality as well as customer satisfaction improvements in Booking & Ticketing, Passenger Information and Comfort & Services are evaluated in these models. Results of both models are used within a mode choice model to assess the effects of technical solutions on the modal share of railway for two use cases: High Speed and Regional rail traffic in Europe.

Through the development of Multinomial Logit models the number of passengers per mode per hour during the morning peak can be calculated while considering passenger valuations of service variables as well as supply constraints. An optimisation model is introduced to reflect the influence from changes in LCC on profit maximisation for high speed rail and social welfare for regional rail transport. The LCC change for the optimisation model is provided through the KPI model. For the service variables, inputs from the KPI and customer experience model are used, namely a reduction in delay minutes and an increased frequency from the KPI model and an increase in customer satisfaction variables from the customer experience model.

Sensitivity analyses were carried out using Swedish value of time. The results indicate that customer experience is more important for High Speed traffic than for

Regional while for Regional an increase of frequency in peak hour shows a considerable effect. Further it has been found that a reduction of operating cost does not have a large direct impact on the modal split.
As the results are overall in line with results from desktop research, it can be assumed that the results of the developed model framework are solid. To further stabilise and improve the results, the experts of IMPACT-2 will especially work on stabilisation of the data input for the model framework. Once the data of all models are stabilised, the results will give a good indication on how technical innovations developed within Shift2Rail will impact the actual shift to rail.

Keywords: European railway system, comprehensive assessment, model framework, mode choice, KPI, customer experience.

1 Introduction

The European initiative Shift2Rail has the goal to enable the railway system to be a major part of the solution towards sustainable mobility. To achieve this goal, a variety of research activities has been launched, developing innovations in fields of rolling stock, infrastructure, control, command and signalling, IT solutions and freight rail, as well as investigating needed actions for topics such as standardisation, noise reduction and energy consumption [1].

In the IMPACT-2 project three models are developed to display the impact Shift2Rail can have on the European railway system: the KPI model, the customer experience model and the mode choice model. The KPI model is developed to assess the effects of the Shift2Rail research results on Life-Cycle-Cost (LCC), Reliability & Punctuality and Capacity [2]. To compliment the KPI model, the customer experience model is being developed. It assesses the effects Shift2Rail can have directly on customer satisfaction, especially in the fields of Booking & Ticketing, Passenger Information and Comfort & Services [3]. Finally, the mode choice model takes into account the results of the KPI and customer experience models and assesses the change in modal split [4].

To investigate the factors influencing the rail demand, a literature review has been done. Blainey et al. [5] mention the following important barriers: travel time, ticket price, service frequency, network coverage, station access, egress and interchange. In the context of high-speed rail market, existing studies mainly focus on estimating elasticity of ticket price [6], service frequency [7] and interchanges [8]. However, only a few studies looked into other factors such as Comfort & Services [9] and Booking & Ticketing [10]. Moreover, improvement in LCC may also have an indirect effect on rail demand due to its impact on the economy of operators. This paper therefore proposes a comprehensive framework that systematically evaluates Shift2Rail innovations by using the three models.

For this, two types of data are necessary: baseline data to describe the railway system as of 2013 and improvement data that express the influence of the Shift2Rail innovations towards the objectives of the three models. Through different sources from industry, infrastructure managers and railway undertakings, research institutes and European railway authorities, as well as a high expertise within the IMPACT-2 project, coherent generic baseline scenarios are developed for the models. Onto these, the improvements from the Shift2Rail innovation projects are assessed towards their contribution to the Shift2Rail goals.

2 Methods

To be able to make a statement about the Shift *to* Rail, all three models need to work together. Double counting of effects within the models must be avoided. In doing so, their connections need to be defined clearly.
The KPI model yields three final results: a percentage change in LCC, Reliability & Punctuality and Capacity for a chosen scenario. For the integration with the mode choice model, intermediate results of the KPI modelling are needed. Namely these are: Rail track charges, Operational cost (including cost for rolling stock), morning peak frequency, maximum usable track capacity and average delay minutes per train. The KPI model is able to provide these values without further adaption as they are main components for the end-results.
The customer experience model captures the percentage of barriers to travel by train which can be removed thanks to innovation such as offering one-stop-shop application for booking, ticketing and information about a multimodal trip, designing more comfortable and less noisy trains and improving services in the stations. Assessment of removal of barriers, i.e. customer experience improvement, targets three main fields: Booking & Ticketing, Information and Comfort & Services, which can be included without further adaptation in the mode choice model.
With these input Multinomial Logit models are developed for mode choice calculations. Two use cases are presented: For the high-speed rail use case, Bus, Air and Private car are considered as competing modes, while Bus and Private car are considered in the regional rail case. A linear utility form (U_{rail}) is adopted as shown in Equation (1) [4]:

$$\begin{aligned} U_{rail} = {} & AlternativeSpecificConstant_{rail} + (\beta_{rail}\mathrm{DisU}^{LoadFactor})InVehicleTime \\ & + \gamma_{rail}TicketCost + \cdots + \delta_i Attractiveness + Errorterm_i \end{aligned} \quad (1)$$

Parameters β, γ and δ reflect passenger valuations of service variables. The model predicts the number of passengers per mode per hour during the morning peak under the supply constraint that the predicted demand cannot exceed train capacity. A crowding factor ($DisU^{\,LoadFactor}$) is also considered.
An optimisation model is adopted to evaluate the improvement in LCC on rail demand. For the high-speed case, it is assumed that the operators will maximise their profit (which is a function of rail demand calculated by the Logit model) given the operational costs and rail track charges. In the regional case, it is assumed that the operators will transfer all the profits obtained from reduced operational cost, due to improvements in LCC, to the passengers through a decrease in ticket price and/or an increase in service frequency.

3 Results

To visualise the interfaces of the models the model framework depicted in Figure 1 is used. On the one hand, results of KPI model and customer experience model will serve as direct inputs in the mode choice models. More specifically the reduction in delay minutes from the Reliability & Punctuality part of the KPI model, the increased frequency and load factor from the Capacity part and the increase in customer experience variables from the customer experience model will service as key service variables in the utility function described in Equation (1).

On the other hand, the improvements in the LCC part do not directly influence passengers' mode choice. In this study, it is assumed that the improvement contributes to lower ticket prices or the possibility to increase the number of departures, which influences the rail demand. This process is captured by the profit (for high-speed) and social welfare (for regional) optimisation models described above.

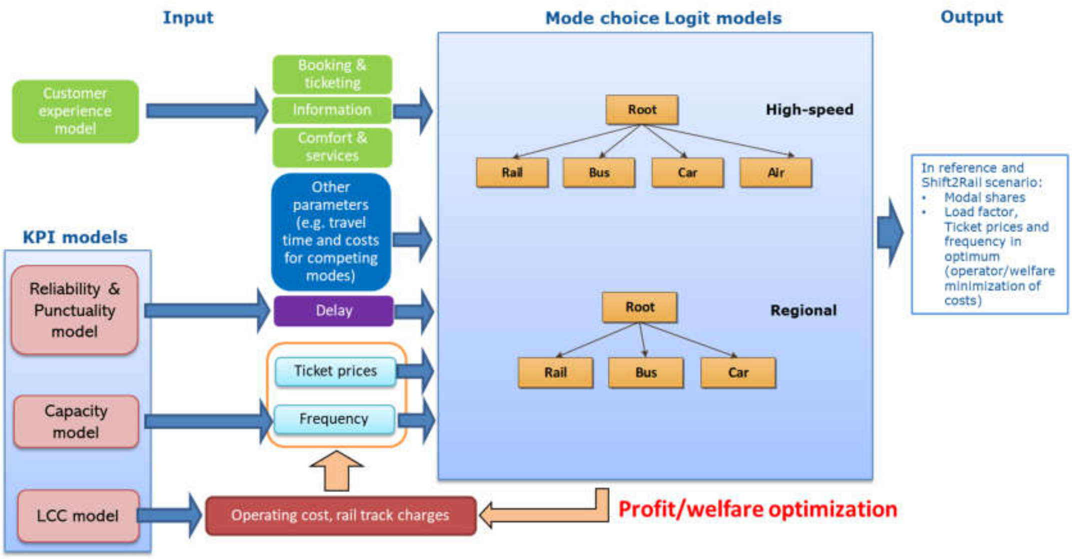

Figure 1 Integration of the three IMPACT-2 models.

A sensitivity analysis is carried out for the high-speed and regional case with Swedish values of time [11]. Results are presented in Figure 2 and Figure 3.

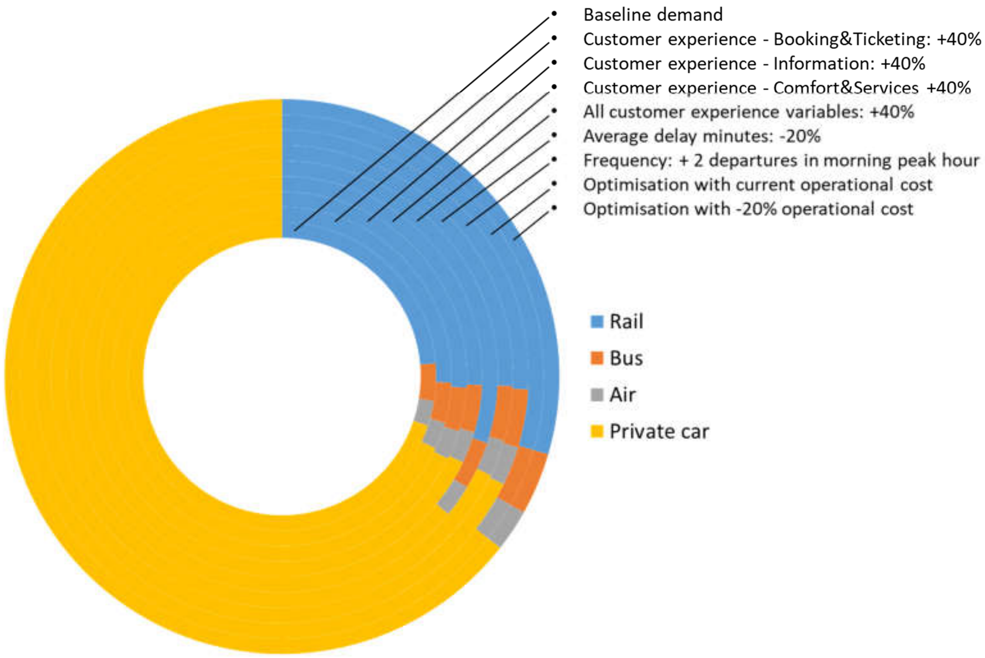

Figure 2 Sensitivity analysis of the high-speed passenger rail case.

It can be found that customer experience variables play a more important role in influencing high-speed rail demand than in regional rail demand, as the elasticities of customer experience variables are higher for high-speed (8.3%-9.9%) than for regional (3.0%-4.4%). The values are also in line with existing studies [9][12].
Improving delay has a moderate effect in both high-speed and regional cases with elasticities around 9%, which is close to the estimates in the literature [13]. Increased frequency has a major impact in the regional case due to the low frequency in the baseline (two departures per hour).

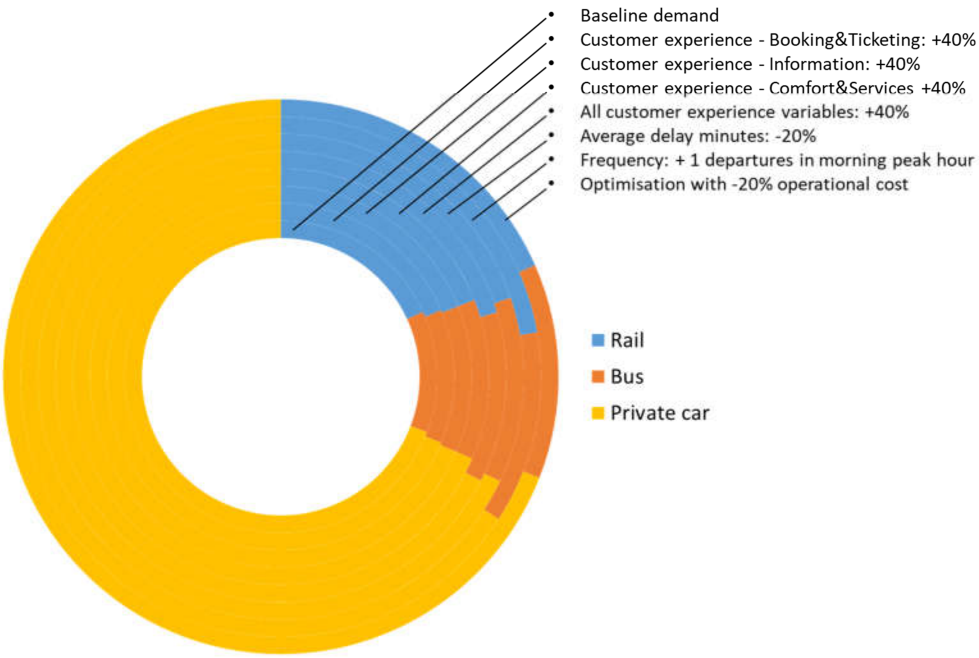

Figure 3 Sensitivity analysis of the regional passenger rail case.

Decrease in operational cost has limited impact on rail demand. In the high-speed case, the operators are willing to operate with maximum usable capacity and decrease ticket cost to attract as many passengers as possible to increase revenue even with the current operational cost. Therefore to further decrease the operational cost does not change their strategy. In the regional case, the revenue from reduced operational cost is too small and hardly leads to a significant decrease in ticket cost or increase in frequency.

4 Conclusions and Contributions

The model framework developed in this study systematically evaluates the improvements of Shift2Rail through the results of the KPI and customer experience model and their integration in the mode choice model. The applicability of the model is tested through use cases for high-speed and regional rail. Thereby, the impact of improvements in LCC is assessed by an optimisation framework. It could be found that model results are in general in line with existing literature. The results highlight the important roles of customer experience variables as well as Reliability & Punctuality and Capacity, but do not find significant impact from improvements in LCC. The model framework provides a foundation to further predict future rail demand.

Accuracy of the mode choice model results is driven by the quality of data provided both by the KPI and the customer experience model. A comprehensive assessment approach has been developed to ensure that the results obtained from all models are applicable for many railway lines in Europe. This could be achieved through an extensive data collection process containing input data from many countries and disciplines as well as ensuring coherency between data, smoothing over sensible

data and developing approaches to make data comparable. Furthermore, disclosing differences in wording and definition of the data as well as the setting of common thresholds ensured reliable results on a European level.
Nevertheless, especially regarding the customer experience model, there is an on-going development to make data more reliable. More specifically, baseline data regarding the balance between obstacles to travel by train are a mix of literature review and expert guesses for now. Those data should become more reliable and accurate thanks to the results of a passenger survey conducted amongst several countries across Europe. Another direction to improve results on the mode choice model level is to test the scenarios where level-of-service of competing modes is improved. For example, lower values of time for private car could be tested, since it is probable if there is a breakthrough for self-driving cars. Another suggested test is a substantial increase in air travel prices, which is probable if more attention is put on the climate change in the future.
Concluding, the IMPACT-2 project will further strive to improve its results on assessing innovative railway technologies' impact on mode choice to evaluate the potential of the railway system to be a major part of the solution towards sustainable mobility.

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