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## Road and Rail Infrastructure III

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## REGIONAL RAILWAYS: TIMETABLE-BASED LONG-TERM INFRASTRUCTURE DEVELOPMENT

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### Abstract

In regional traffic, we are confronted with an ageing railway infrastructure with both ridership decrease and a poor structural condition, interlocked mutually: Investments are hard to justify because of low traffic loads, but service improvements are bound to fail due to the inadequate infrastructure. Therefore, a smart, iterative design process must be started. Taking into account future structural changes and demand shifts, a target timetable is created. First, a demand model for the planning area is set up and calibrated against the current traffic flows of both public transport (train and bus) and individual transport. Second, a prediction of future population changes and structure developments (settlement and road infrastructure) is set up and woven into the demand model. Third, the demand model is fed with the future data and the current timetable to check the development without measures. Fourth, a sensitivity analysis of competing timetable models is checked against the demand model; a detailed analysis of these results is then taken to optimise the best-ranked timetable model. Next, the design of a more detailed timetable can start. By means of an integrated timetable model, the operationally necessary riding times between hubs as well as along the track are defined as well as the rough location of two-track sections. These parameters are then taken over to check infrastructure as well as vehicle options to achieve these goals. In a project-wise analysis, the optimal combination of infrastructure measures is then obtained to be able to run the predicted timetable. Since this timetable has been put beyond dispute beforehand, every single infrastructure measure can be justified including all consequences that result from its implementation. This results in a step-by-step upgrade plan and a definitely optimal, long-term and timetable-based infrastructure development perspective.

*Keywords: regional traffic, railway, timetable, infrastructure, target network*

### 1 Introduction

Regional Railways generally face two problems: decreasing ridership and an ageing, mostly inadequate infrastructure. Additionally, these two problems are highly interlocked, since public spending on railway lines on the decline cannot be justified. This results in unattractive conditions for passengers, further decreasing the ridership and leading to the ever-so-often cited vicious cycle. Most examples of successful regional railway lines around the world arose either in times of general readiness to invest or as a result of lobbying of strenuous pressure groups. However, neither of these prerequisites is guaranteed and neither reflects the actual potential of regional railway lines, both leaving the commitment for regional railway traffic and its long-term development highly subjective. What both communities and railway infrastructure operators need is a clear business case and a long-term development perspective to allow for a transparent decision concerning future service offer as well as infrastructure upgrades.

## 2 Objectives

As mentioned above, regional railway traffic is often not only confronted with a limited commitment to investment, but also with an unstable forecast concerning its long-term perspective. Due to the long service lives of railway infrastructure, this combination usually leads to a mere persistence at the status quo, leaving necessary re-investments unaccomplished, hampering upgrade measures and rendering significant service offer modifications impossible.

The process presented here covers this special situation of regional railways. The objective is a long-term infrastructure perspective based on a target timetable and an economically optimal set of measures to achieve that goal. The timetable is decided upon at an early stage and put beyond discussion by means of demand modeling. Since the target is clear and all measures align with it, every single investment and its timeframe can be justified with the long-term development plan – and also, political influence can be channeled along transparent decision parameters.

## 3 Methodology

The methodology presented here is an adaption of a classical iterative engineering design process [3], suitable for regional railway lines. It requires a demand model, a population and structure prediction on community level, a detailed knowledge of current railway infrastructure conditions and a thorough base for railway upgrade measure design at several fields of engineering. The main features of this process are the interdisciplinary feedback loops, comprising demand modeling, timetable construction and upgrade measure design in the fields of infrastructure projects, operational measures and vehicle characteristics.

### 3.1 Demand modelling

The approach requires a well-kept and calibrated multimodal demand model capable of modelling modal shift and sensitive to timetable changes. This model is fed with the current population, structure and timetable of all means of public transport. It is calibrated upon both ridership of public transport and road traffic load profiles. Furthermore, it is checked against actual travel time and travel distance distributions. The latter is of great importance especially in regional transport, as it accounts far more for the load profile compared to urban transport. It should be noted here that the creation and calibration of the demand model as well as the quality of the input data is crucial for the whole design process. This is why at this stage, trade-offs concerning workload or project speed pose a great danger for the quality of the whole process.

An important aspect in the demand model is the need for a service responsive demand recalculation, meaning a recalculation of the complete demand matrix rather than a mere redistribution of static OD matrices for each mode.

The demand model plays an important role throughout the whole process and will be fed with new information in several project stages in order to produce new input data for the other fields of design.

### 3.2 Population, structure, and infrastructure prediction

Since the demand model is calibrated to model the status quo, but will be used to model the future demand and ridership, a set of predictions is included in the demand model. A simple traffic volume increase, as often used, does not reflect the problem at all: Especially in rural areas, traffic volume will depend upon a wide range of demographic characteristics, such as age distribution, car ownership and education, which will in many cases result in a traffic volume decrease rather than an increase, as well as in a shift of peak hours.

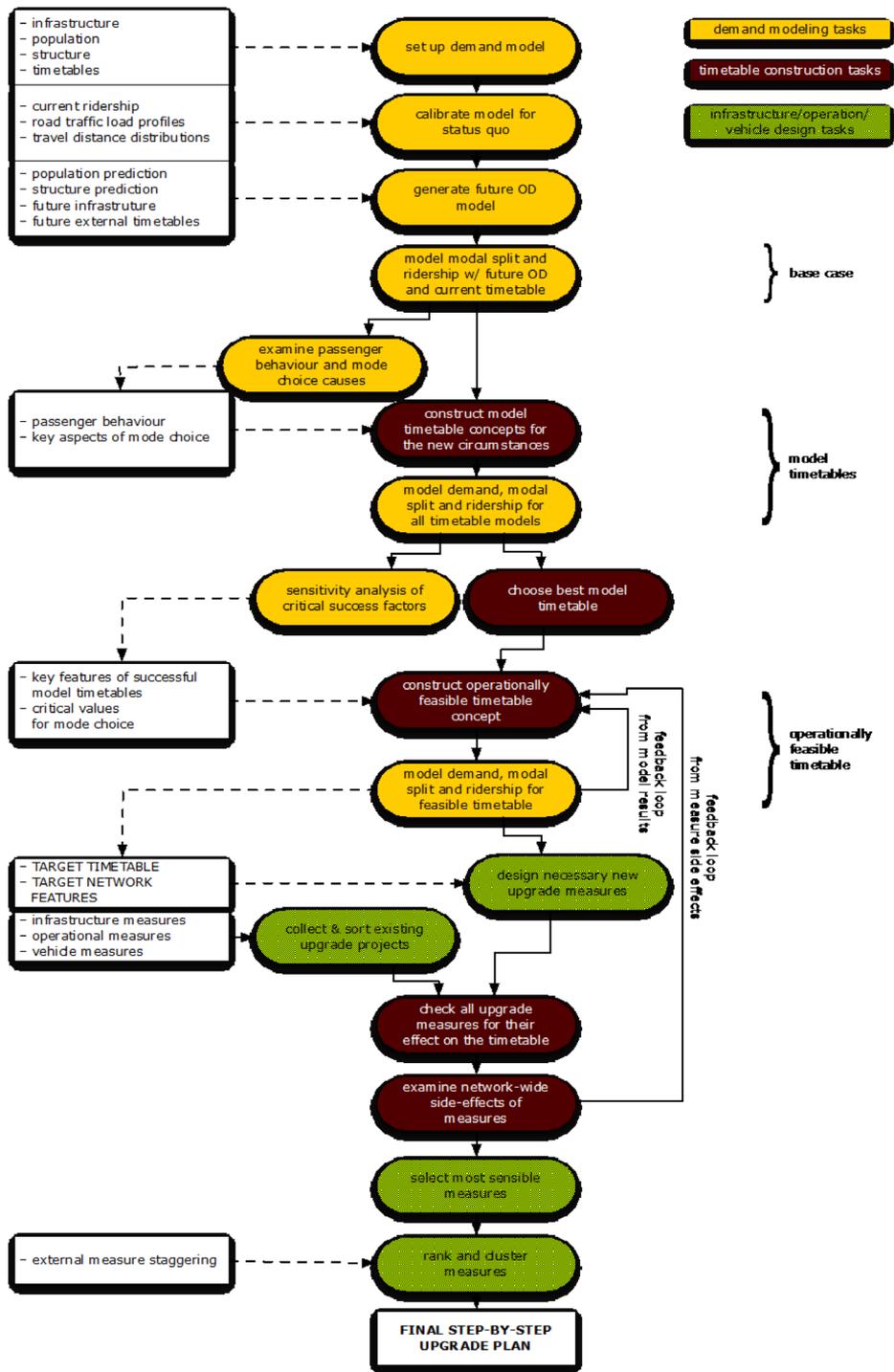


Figure 1 Workflow of the methodology

Therefore, population predictions must include at least an age distribution; structure predictions must comprise workplaces, schools, higher education, and public offices, thus reflecting future administrative changes. Infrastructure predictions need to concern all areas of traffic not touched by the upgrade plan (road network extensions/modifications, upgrades/closures of surrounding lines, etc.) to ensure that all comparisons refer to the planning horizon.

### **3.3 Case design**

Since all upgrades target at a future point in time, the cases taken into account for comparison also need to reflect this future – representing what would happen if no action was taken. The design cases are based thereupon and represent changes in the service offer to be compared with the base case. All comparisons are made within the demand model, so the complete demand matrix and the modal split need to be recalculated at every step. This is, in planning areas typical for regional railway lines, a time-consuming process. There is, however, no alternative to this step, since a complete demand recalculation is not only desirable, but crucial for the iterative design process.

#### **3.3.1 Base case**

The base case, upon which all other evaluations are to be based, needs to reflect both the future population and structure, but also the future infrastructure apart from the regional railway line in question. This leads to a case with all circumstances of the future, but with the current, meaning unchanged, regional railway infrastructure and timetable. If the current timetable and infrastructure do meet the future demand, this means a no-action strategy is sensible; if not, the reaction of passengers to structural changes will be evident.

#### **3.3.2 Model timetables**

An examination of passenger behaviour then leads the way for model timetables. The purpose of model timetables is not to deliver an operationally feasible timetable, but to derive trends from extremal approaches to tackle the identified demand problems. A tight station spacing, for example, suited for a regional area coverage, contradicts the need for a competitive riding time. Also, the ridership increases with a denser interval, but there is a certain point after which the additional costs for an improved offer outweigh the ridership increase.

Model timetables should differ in no more than one property each – interval, station spacing, riding time, product structure – to allow for an isolated comparison of trends. This, in turn, leads to an exponentially growing number of comparisons, since all trends are derived from pairwise comparison. Therefore, the differences between the model timetables should be as extremal as possible. The result of the model timetable comparisons then leads to two further steps: the selection of the key parameters of the model timetables that proved successful in the demand model leads the way to the construction of an operationally feasible target timetable. Meanwhile, the results obtained in the demand model from comparing the model timetables are used for a sensitivity analysis. This is to retrieve critical values to be obeyed by the target timetable.

#### **3.3.3 Feasible timetable solution**

The purpose of the model timetables was the demonstration of demand and ridership effects of various timetable approaches. An operational feasibility would not only be unnecessary, but also potentially handicapping: since the scope of upgrade measures to obtain operational feasibility is highly subjective, such a timetable could also obscure possible improvements. The next step, creating an operationally feasible timetable, includes as many characteristics as possible from the successful model timetables of the preceding step, while the previously identified critical values serve as limit values. These limit values guarantee that the main goals (ridership, modal split) will also be reached by the operationally feasible timetable. The feasible timetable is constructed within a standard timetabling routine. However, restric-

tions such as switch speeds, level crossings or slow orders need to be removed in the design process. The maximum speeds on the open track take into account the alignment only, and the (virtual) existence of double-track sections is handled flexibly according to the needs of the timetable construction.

This timetable solution aims at constructing a framework for a target timetable when it comes to riding times between hubs, necessary transfer connections and the rough location of double-track sections. While it would, in principle, be possible to fix the exact location of all double-track sections as well as alignment and other measures, it is not the goal at this very stage. Since the exact measures that are to be contained in the upgrade plan are highly interdependent, any fixed measure at this stage will lead to undesired restrictions.

### **3.4 Feedback loop**

As noted already, the feedback loops between the demand model, the timetable construction and the measure design play a vital role in this design process. After the cases have been designed and the model timetables have been evaluated in the demand model, an important feedback loop is started: taking all results obtained, the key success factors of the various timetable approaches need to be worked out. After narrowing down the extremal values of the model timetables, the aforementioned critical values can be obtained, such as the maximum acceptable riding time and the optimal interval as well as the (both positive and negative) impact of station closures or relocations. This is done by modifying the parameters in question until the target performance indicators (modal split, modal shift, ridership, etc.) are reached. This information is necessary for supplying the feasible timetable solution with limit values not to be exceeded. The second feedback loop takes place after the feasible timetable solution has been completed. In the demand model, the performance of the feasible timetable is evaluated and checked against the target performance indicators (modal split, ridership, passenger load, etc.) as well as the performance obtained with the model timetables. Clearly, the feasible timetable will feature certain compromises, since not all target aspects will be met equally by the feasible timetable. Nevertheless, the key features obtained from the sensitivity analysis must not be exceeded so as to remain attractive enough for passengers to meet the target performance. If the demand model shows a performance too poor to be accepted, the feedback loop ensures that modifications can be made in the timetable without lost work in the measure design.

### **3.5 Target network features**

Clearly, the feasible timetable solution will be close to the final target timetable. It will, however, still offer enough flexibility to allow an optimisation of the infrastructure measures. What is needed for this next step is a definition of the target network features to allow the target timetable to be operable.

The target network features to be retrieved are the target riding time between hubs as well as between stations/double track sections, the rough location of double track sections and the required station layout (with an emphasis on parallel approaches/exits and cross-platform transfers). Since there is a high grade of interdependency between almost all possible measures, the exact location of double-track sections and the exact station layout can only be determined within the measures design process.

### **3.6 Infrastructure, operational and vehicle measures**

Finally, all target network features need to be achieved via an optimal arrangement of measures. In the judgement and selection process, the methodology of Uttenthaler [1] was chosen. This simple approach allows a flexible assessment of measures. All measures in a section in question, yet grouped when necessarily combined, are listed with their individual riding

time benefit. Since the necessary riding time reduction is known, the addition of potentially every measure combination is possible to achieve the target riding time. The most cost-efficient and/or most beneficial set of measures allowing the target riding time is then selected and included in the target network measures. Certain measures, such as the electrification of a line or vehicle characteristics, affect the whole line rather than individual stretches, so they have to be added or subtracted along the whole line. Alongside traditional alignment measures, there is a wide variety of measures that allow riding time reductions at lower costs with comparable benefit [1]:

- **Travel time reserves:** In an integrated timetable, travel time reserves are usually bigger than in non-cyclic timetables, since disruptions lead to either lost transfers or a network-wide spread of delays. Therefore, riding time improvements at the cost of riding time reserves should be avoided completely or be only of temporary nature.
- **Vehicle dynamics:** One often untouched parameter of a railway network is the vehicles' capability of better acceleration or deceleration. This is especially important in regional railways, since with short station spacing it makes up a great percentage of the riding time. An electrification of railway lines, which leads to a significant improvement of the vehicle dynamics, can be justified via the necessary riding time reduction. In stations, however, a better acceleration leads to a higher speed at the station gridiron and will therefore require a change of the switch geometry. This, in turn, usually can be obtained at manageable costs, especially in the long run.
- **Number of stops:** Regional railways normally feature a dense sequence of stations for a area coverage. However, railway stations often have been built well outside settlements upon construction of the railway line and have not been repositioned since. Additionally, the current and future mobility structure with a high grade of intermodality decreases the need for small stops with a limited amount of passengers. Compared to the amount of time potentially gained by alignment measures on the comparatively short stretches of open track in regional railways, a stop left out will lead to a fair amount of riding time decrease.
- **Stopping time:** regional railways typically do not feature many stations with great passenger volume. Therefore, the practical time needed for stops is often less than the typical design value for stopping time in regional railways, 30 seconds. Shortening that time to the actual needs results in further riding time decreases, albeit in a small scale.
- **Uncompensated sideways acceleration:** Regional railways typically run with low axle loads due to light vehicles. The limit values for free sideways acceleration, however, typically cover a range up to heavy freight trains. Without tilting technology, uncompensated sideways accelerations of up to  $1,1 \text{ m/s}^2$  are acceptable internationally, with the light vehicles not affecting the superstructure more than considerably heavier trains at lower sideways accelerations. This leads to a better exploitation of the alignment and riding time decreases in similar dimensions as alignment measures.
- **Switch geometry:** train stations are often equipped with tracks long enough to serve freight trains. Together with the standard geometry of switches, this often allows no more than 40 km/h for a long stretch before the platform. If the switch is optimised to the approach speed to be expected at the very location of the switch, the full track design speed can be exploited over a maximum stretch.
- **Level crossings:** regional railways usually feature a great number of level crossings without technical safeguarding. This affects the possible track speeds for security reasons. Therefore, a technical upgrade of level crossings has a significant effect on the riding time on regional railways.
- **Station layout:** While all other measures aim at a direct decrease of riding time, the station layout cuts the required riding time reduction. The main application of a redesigned station layout are transfer stations, since a parallel departure/arrival shortens the headway between two trains and therefore the required riding time reduction of one of the trains. At stations with train crossings, pedestrian level crossings prohibit parallel approaches, so a technical safeguarding or an underpass reduce the required riding time reduction.

- **Signalling:** alike the station layout, signalling affects the possible headway and therefore the required riding time reduction. Signalling does, in practice, often affect the main speed on the open track, too, but since any changes in track speed would be futile without an adaption of the signalling system, we assume that this is carried out anyways.
- **Alignment measures:** Finally, alignment measures form the traditional, but usually most expensive riding time reduction measures. Apart from classical alignment projects, the application of optimised curve design for small angles and small radii leads to a significant increase of track speed without much deviation from the old alignment [2].

### 3.7 Step-by-step upgrade plan

With the final target network defined and the set of measures fixed, the next step is a bundling of measures into sensible packages. Therefore, a set of intermediate timetables is defined, so that the logical succession of the upgrade measures can be derived from these intermediate steps. In accordance with the upgrade plans of surrounding railway companies and the succession of these projects, the amount of measures taken too early can be reduced to a minimum and key projects can be prioritised.

## 4 Application

The methodology presented here is currently applied to the network of Graz-Köflach Railway (GKB) in the south west of Graz. The design horizon is the year 2025, which aligns with the target network of the Austrian Federal Railways (ÖBB) upon completion of the Semmering Base Tunnel and the Koralm Railway Link, both heavily affecting the planning area. The following data was obtained from several sources and is used as a design basis:

- The company strategy of GKB;
- The national, regional and local transport strategies of the republic of Austria, the province of Styria and three districts touched by the railway network;
- The national target timetable of the Austrian Federal Railways with the integrated timetable hub at Graz;
- The population and structure predictions of the province of Styria;
- The planned road network extensions of the province of Styria.

The demand modelling process and the timetable design have already been finished, while the measures planning process is still underway. So far, it has been shown that:

- 1 the population and structure predictions show a growth and a concentration of the population around the cities, while the more remote areas face a further population decrease;
- 2 the various timetable models developed show a clear preference to close down several smaller stations to allow for a competitive riding time between the bigger cities;
- 3 the demand model allows for a level of timetable judgement as detailed as necessary for regional railway networks, especially when it comes to a sensitivity concerning interval and stopping policy;
- 4 the necessary measures can be reduced to a few double-track sections, the technical safeguarding of level crossings and a big emphasis on switch geometry in stations;
- 5 the step-by-step upgrade plan is an effective and absolutely objective tool for negotiations about the future of the regional railway network.

Detailed analyses of the measures necessary for the target timetable are currently being conducted. The project is due to be completed by summer 2014. When finished, the railway network is supplied with a long-term upgrade concept without the need for short-handed negotiations about singular measures.

## 5 Conclusions

The approach presented here is, in general, nothing particularly new, since any design process in engineering will be based upon a design load and the dimensioning thereupon. However, the timetable oriented design process is still rather new in railway infrastructure, the use of demand modelling in an iterative railway infrastructure design process has not been carried out in this degree of profundity before and especially not in regional transport.

There is little chance that the upgrade plan fails at a later stage due to a demur concerning an earlier one, since (i) the demand has been modeled on a solid basis; (ii) the target timetable has been put beyond discussion beforehand; (iii) the measure set is the result of a thorough assessment process; (iv) the succession of the measures follows the outside circumstances and a logical combination of measures; and (v) all feedback loops occur within the design process already. This results in a clear business case as a long-term decision basis for the future of regional railway lines.

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