Public Transport planning: Perfect services all along the line for passengers and planners

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Abstract
Today's society has high expectations regarding mobility: It should be powerful, secure, eco-friendly and inexpensive. Public transport has a key role to play in this ambivalent environment. Therefore, it is important to plan it in an anticipatory and market-oriented manner. However, the design, implementation and operation of public transport systems are demanding tasks. Professional software tools can assist planners in coping with these tasks.
Most important for Public Transport network planning to consider the Public transport supply (e.g. network, services, vehicles) and demand, i.e. the passengers, simultaneously and consistently along the whole planning process.
Thus, a software tool needs to consider model the behaviour of people as well as operational tasks. The paper, if accepted, will give an overview about the capabilities and benefits of an integrated software-based planning and will include among other things discussion about the following topics:
- Analyse service quality purely based on transport supply
- Modelling Public Transport demand
- Connecting supply and demand by different assignment methods
- Including fare models into the analyses
- Calculation number of required vehicles (vehicles scheduling), costs and revenues for different scenarios
- Presentation of the results to the planner and also the decision maker
Goal of the presentation and the paper will be to support decision makers to choose an appropriate level of planning and appropriate tools for their task. Finally, this will improve the level of service in Public Transport, while concurrently not increasing costs or even saving money.

INTRODUCTION

Today's society has high expectations regarding mobility: It should be powerful, secure, eco-friendly and inexpensive. Public transport has a key role to play in this ambivalent environment [3]. However, not only today's situation is demand, the Public Transport sector is facing major challenges in the future. A recent survey [2] identified fewer resources and climate change and demographic change as the major drivers for the Public Transport in the future:

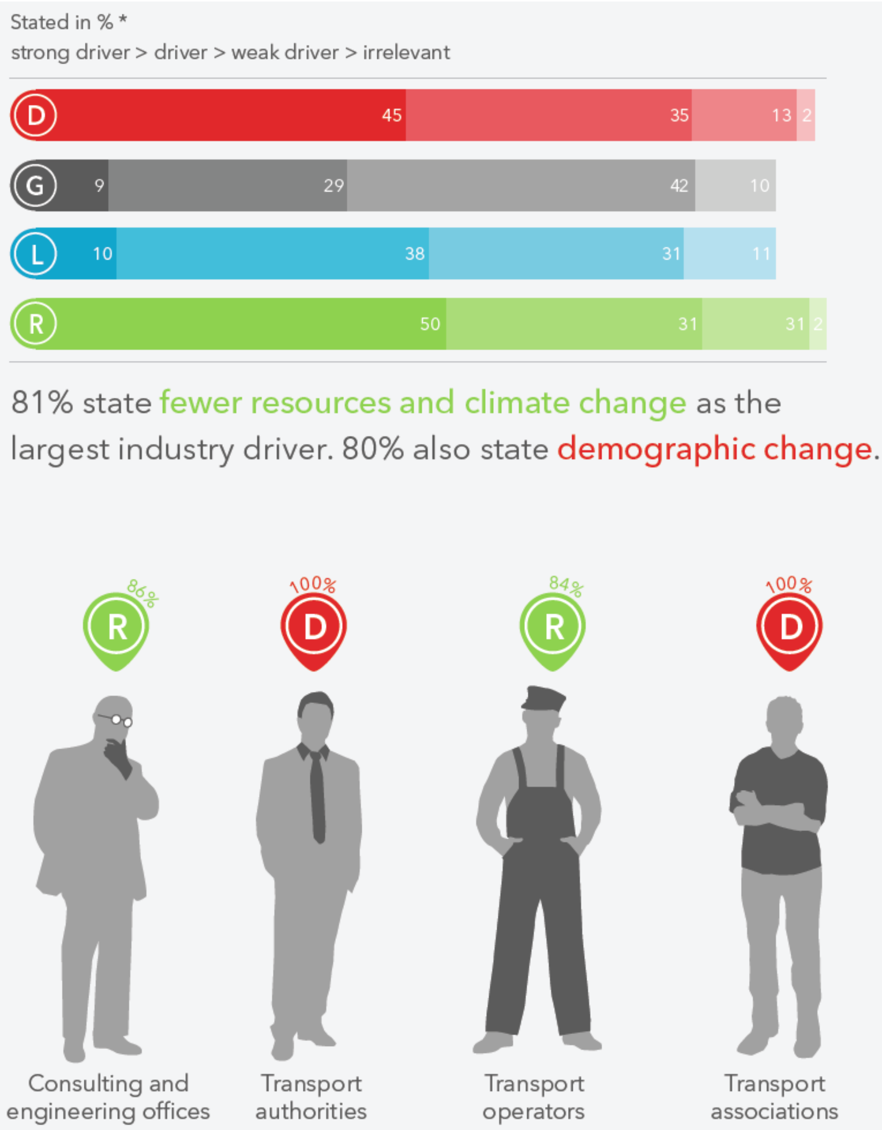

Figure 1: Drivers of future Public Transport planning [2]

Therefore, it is important to plan it in an anticipatory and market-oriented manner. However, the design, implementation and operation of public transport systems are demanding tasks. Professional software tools assist planners in coping with these tasks. A comprehensive planning tool should offer detailed planning and analysis functions, easy-to-interpret display options that cover all strategic and operational processes across public transport planning. Important to note is that it is always required to link the transport demand with the transport supply.

DEMAND-BASED PUBLIC TRANSPORT NETWORK AND SUPPLY PLANNING

One of the classic tasks of network modelling is to provide passengers with an attractive line network that at the same time is efficient from an operative perspective. In terms of spatial planning, this means to determine the line routes and transfer points in the network. Temporal planning, on the other hand, focuses on the optimum headway, the coordination of lines and connections between the stops and the analysis of supply in terms of line performance and output.

Users usually import timetable and network data from common systems and use it for modelling the current public transport supply. Network data is imported via interfaces to geographic information systems (GIS) and timetable information systems, such as Google Transit, HAFAS or railML. Moreover, it is possible to import data from different sources, including automatic passenger counting, vehicle tracking and ticketing systems or MS Office. All services can then be displayed and edited in the public transport network editor, in the tabular and graphic timetable.

In order to analyse the quality of public transport services from the passengers' point of view, planners can use transport planning software to combine public transport supply with statistical data of land use, number of jobs and residents. GIS functionalities shall enable the planner to identify how many residents can reach the next long-distance train station within a given travel time, for example. But users cannot only analyse travel times, there are also detailed parameter analyses to visualise transfer frequencies and waiting times for all connections across the entire network.

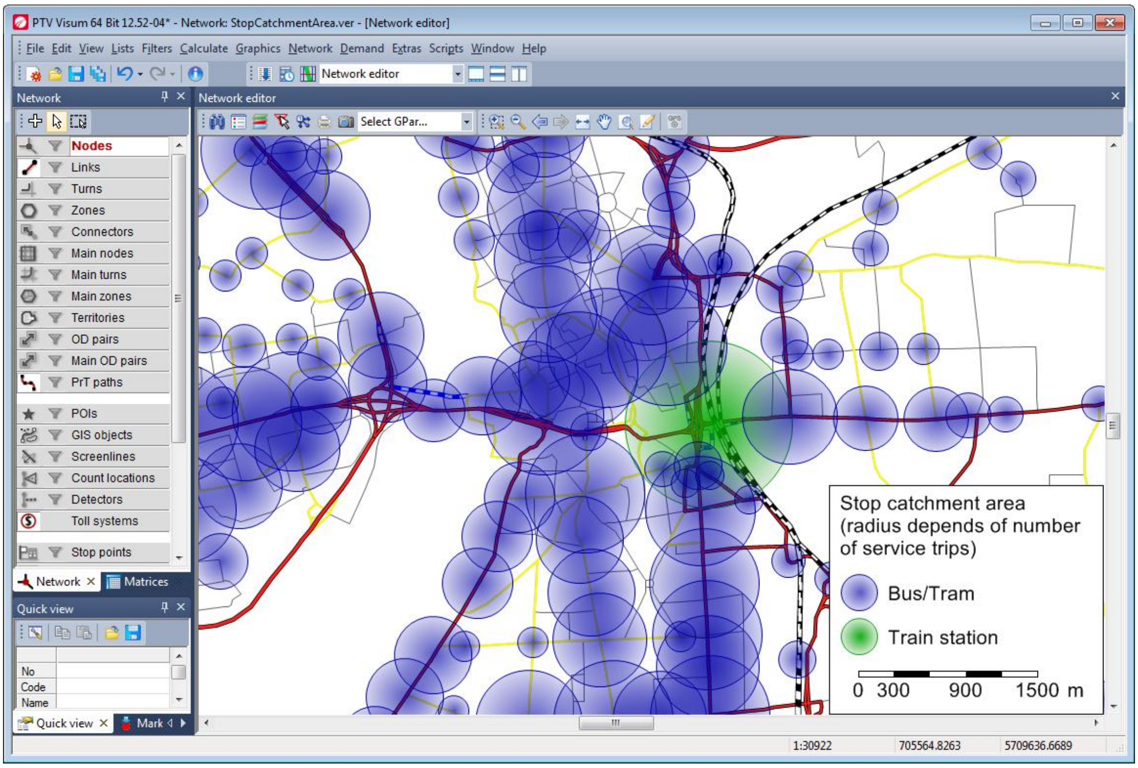

Figure 2: Simple analysis of public transport supply based on stop catchment areas

How attractive new lines, new connections or more frequent services actually are for all passengers and whether these changes will have the effects and impacts desired can best be judged by modelling demand by means of an origin-destination matrix. Such matrix can be created on the basis of public transport survey data or a multi-modal demand model, such as the classic four-stage algorithm. The latter models all passenger choices in both private and public transport – from the choice of the destination to the transport mode and transport connection. This also allows planners to calculate the changes in modal split caused by improved public transport services.

ATTRACTIVENESS – A MEASURABLE BENCHMARK

One can differentiate between three assignment methods which identify possible connections of the passengers for each origin-destination pair and then assign the demand matrix to these connections.

The simplest one is the *transport system-based assignment*, a quite pragmatic approach to conceptual public transport network planning. It does not include any timetable data and does not even require a line network, however it allows users to differentiate between road- and rail-bound transport. Based on demand matrices it models the desired network from the passengers' perspective. This so-called "what-if scenario" indicates which public transport options passengers would chose to travel from the origin to the destination, if they were not limited in their choices.

If there is a timetable, there are two additional assignment methods – the headway-based and timetable-based assignment. The *timetable-based assignment* is often used for timetables with high and regular frequency services. Moreover, it enables planners to create impact analyses of long-term planning scenarios, such as transport master plans which, due to efficiency reasons, do not require detailed timetables to be modelled for each scenario. However, precise information on transfers cannot be included in the assignment without timetable modelling. Nevertheless, users can assign pre-defined transfer times to specific transfers. This includes transfers between regional trains and buses, which can usually be scheduled quite precisely.

The *timetable-based assignment* offers the highest level of detail. It allows for fine-tuned planning and analyses including complex transfers and connections. This means planners can realistically model various effects, such as transfer waiting times and analyse measures for optimising individual stops.

Another important factor for connection choice may be the effects of capacity constraints in the assignment. As a result, overcrowded lines become less attractive due to the large amount of passengers. Just like in reality, in the model, passengers switch to less crowded modes of transport. From a technical point of view, the capacity constraint is included in the impedance calculation of each connection, in addition to other attributes such as travel time and transfer frequency. This additional component can e.g. be a function of the assumed standing minutes on a bus or train. The seats are randomly allocated to the passengers for each stop section – a procedure which is quite similar to the popular children's game of musical chairs.

FARE MODELLING

Capacity utilisation of individual connections is not the only parameter which can be included in the impedance calculation during the assignment. In addition to the classic parameters, such as journey time, waiting time and transfer frequency, it is also the fare which may play a major role. As tariff structures are often complicated, a software tool shall allow users to model any type of fare and tariff model in all their facets including dependencies. This, for example, means multiply-counted zones for a city centre can be combined with short-distance tariffs or transitory tariffs for different transport associations.

If fare prices have been modelled in detail, they can be accounted for during assignment. The assignment method then shows how tariffs influence the passengers' route choice. Consequently, only a few people will take an expensive high-speed train for travelling a short distance if they can take a cheaper local train instead. Moreover, users can analyse the impact of fare changes on revenue. It thus allows transport associations and authorities to check how profitable it is to change a fare or introduce a new ticket type and what is the right price of the ticket to secure revenues.

Once fares are modelled, users will expect that the software calculates revenues distinctly. In other words, it should be broken down into different areas (e.g. transport associations, districts) as well as displayed on the basis of different aggregations (e.g. lines, operators). Flexible revenue distribution models shall enable users to evaluate several performance-based distribution schemes for several operators serving a transport association.

According to [2] cost pressure is a major driver or regular modification of the Public Transport network. Beside the revenue estimation with fare and demand modelling, an importation factor for a cost-efficient Public Transport is the vehicle cost. In order to estimate the number of required vehicles for a scenario, vehicle scheduling (also known as line blocking) is required.

For a complete line costing and revenue calculation, which assesses the profitability and cost coverage of an entire public transport network or its service units, it is also necessary to determine the costs of infrastructure and operations ([1], [4], [5]). An important basis for cost calculation is the number of vehicles required. For this the vehicle scheduling process is crucial. There are two approaches for this task.

VEHICLE SCHEDULING

With a *basic line blocking,* the planner himself defines the vehicle types of his choice. The automatic line blocking procedure completes the process on the basis of the timetable while following user-defined rules. In this context, depots and their capacities are explicitly taken into consideration. Journey-specific preparation and completion times as well as additional activities such as refuelling or cleaning are included as well.

Detailed line blocking provides greater room for manoeuvre. Planners can model forced chaining or optimise the use of vehicles by also taking alternative types of vehicles into account. Instead of selecting a specific vehicle type, planners can then allocate a number of different vehicle types to the trip. The optimisation procedure then chooses the type that ensures a minimum deployment of vehicles. Here, it is again possible to integrate demand. To permit demand-optimised vehicle deployment, the vehicle choice is based on the capacity of each vehicle type in terms of passenger volume generated during assignment or using survey data. At this stage of the planning process, graphical formats such as block diagrams of line blocking results (see e.g. Figure 3) also assist planners in identifying and developing the network's optimisation potential in terms of profitability.

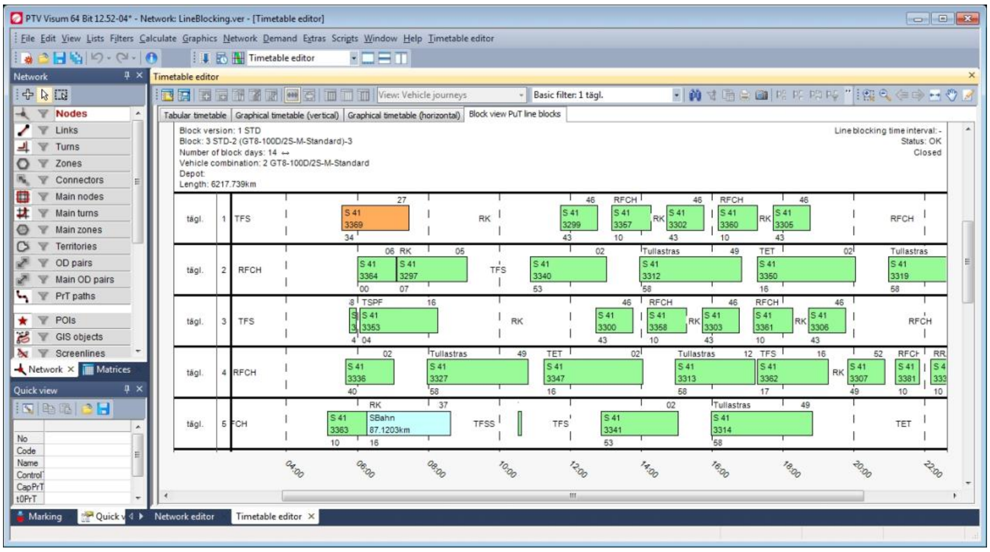

Figure 3: Block diagram: schematic display of the line blocking results.

COMPACT VIEW: THE SCHEMATIC LINE DIAGRAM

Visualisation of results is essential for the success of Public Transport planning. A schematic line diagram provides an important visualisation option (see e.g. Figure 4). Using the schematic line diagram, planners can abstract the network according to their needs. The schematic line diagram visualises the network relationships and gives users an ideal overview of transfer stops. A wide range of graphical parameters and labelling options provide the information required.

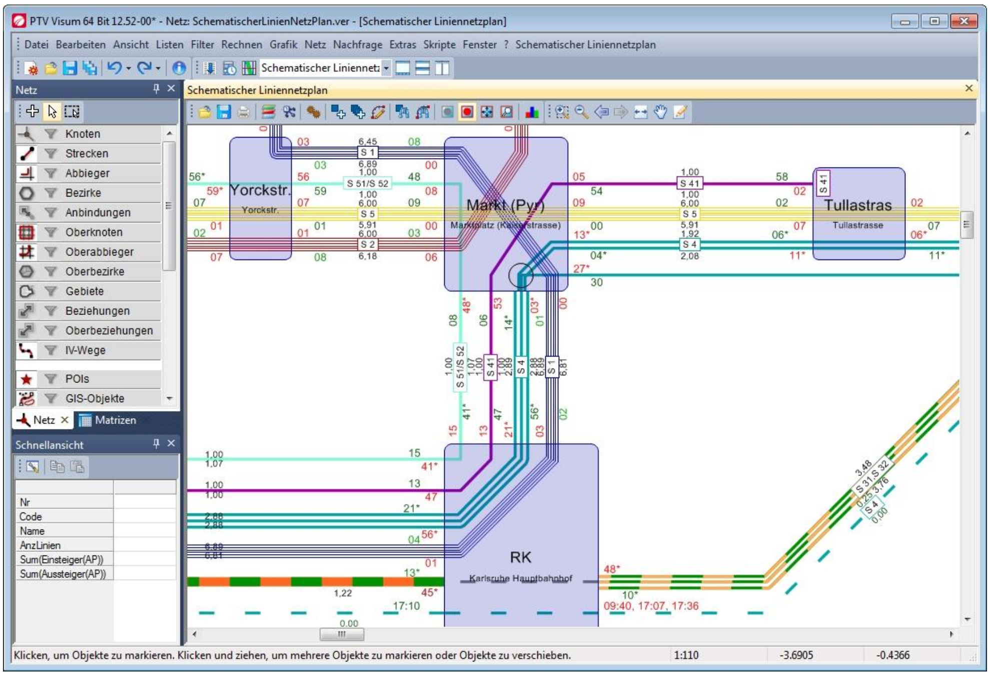

Figure 4: The schematic line diagram provides users with detailed information on stops and routes at a glance

Stops are displayed as boxes to which users may add timetable details. Information on arrival and departure times for all lines is thus provided at a glance enabling planners to ensure services with regular headways across several lines. The links between the selected stops are displayed as edges. Lines, transport systems, and service frequencies can be classified by using bars of different colours and different types of dashed lines.

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