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**Informe Técnico / Technical Report**

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**Ref. No: DSIC-II/01/07**

**Pages: 65**

**Title:** Survey of automated Systems for Railway Management

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**Date:** 10/01/2007

**Key Words:** Railway Management, Timetable Optimization, Capacity Analysis, Atomated System

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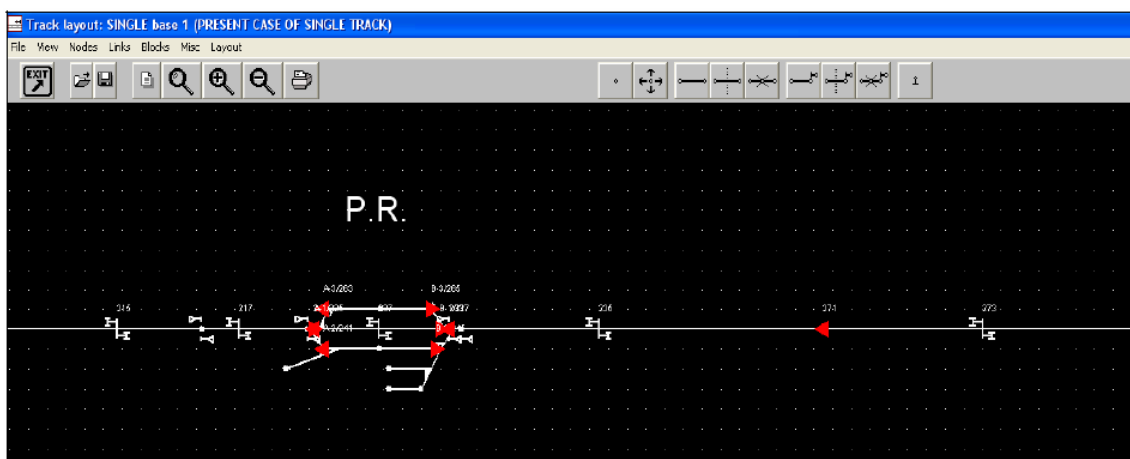
## 1. RAILSYS

([http://www.rmcon.de/englisch/uber\\_railsys.html](http://www.rmcon.de/englisch/uber_railsys.html))

RailSys uses a microscopic description of the real world in the model to reduce the risk of wrong decisions based on an inexact planning. The program has been developed by the University of Hannover and RMCon, Rail Management Consultants. It has been applied successfully in different projects such as the high speed lines Cologne-Rhein/Main and Sydney-Canberra, the city railways of Munich, Cologne, Sydney, Melbourne... or the rail network in Berlin and Copenhagen.

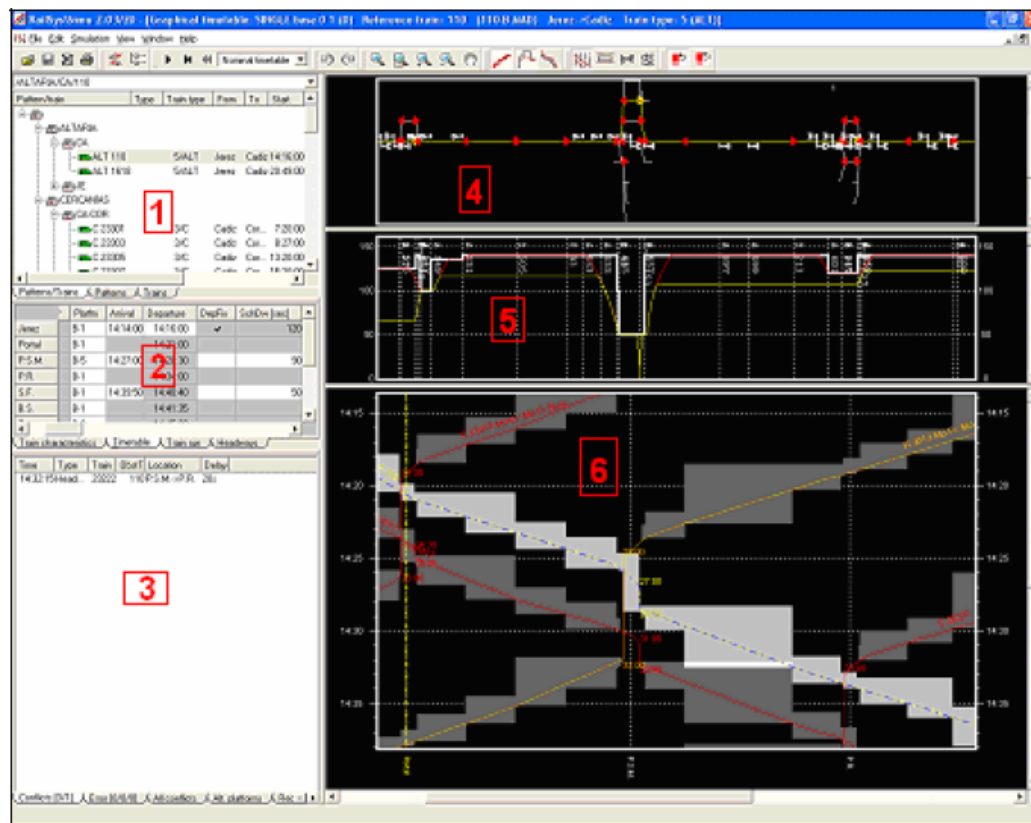
RailSys consists on four modules:

- **Infrastructure manager** (STED), its function is to model the existing infrastructure and to build up different infrastructure variants. This editor allows to model with an accuracy of one meter. The modeled elements of the infrastructure include switches, signals, stations, speed indicators, platforms, stop boards, routes... and they contain attributes about track parameters like length, gradient, max. speed... This module contains several alternatives to refer the signalling system, such as ATC (Automatic Train Control) or M/P (main signal/presignal), or referring to the interlocking machine. The starting point is the usual partition of the rail network into stations, junctions, and sections connecting them. The infrastructure is built up as a succession of nodes and links in RailSys, where a link symbolises a track and a node is either a connecting point of several links or a location for signals and other elements.



*Microscopic network display in STED (infrastructure manager of RailSys)*

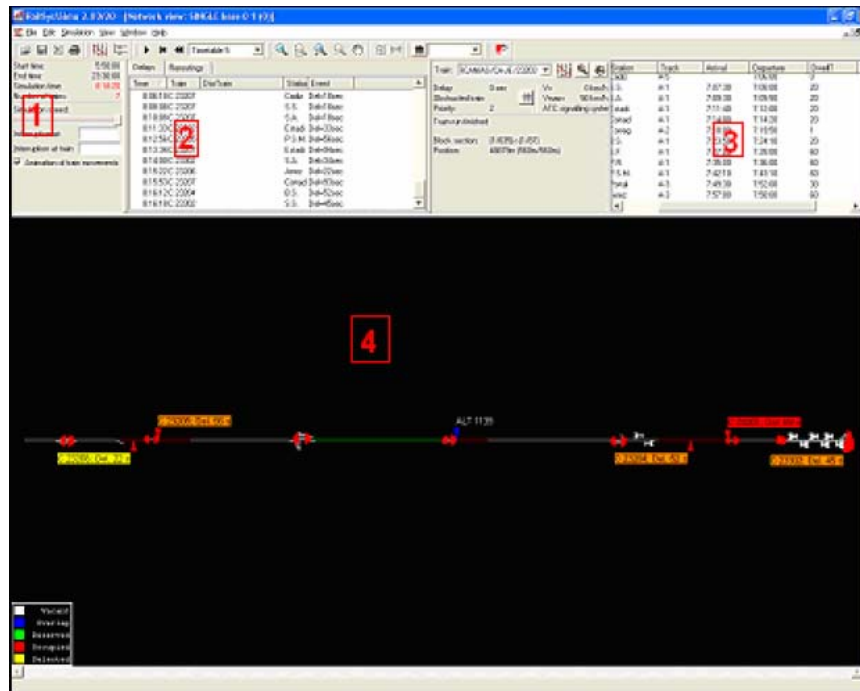
- **Timetable manager:** the program is ready to get the exact running time calculation and they are transferred into the timetable construction phase done with SIMU; according to this, it is possible to see the effect of any track change or other changes immediately. In this module, exact routes and different alternatives are set for every train, apart from the definition of the characteristics of the rolling stock (acceleration, deceleration, train length, priorities, train patterns...) and other dispatching rules. The main task of the program is the optimal allocation of locomotives in large lines or networks, so it indicates inconsistencies such as unfeasible connection times, not enough headways and conflicts with other trains.



Display of timetable manager:

- 1- Hierarchic train and pattern list
- 2- Timetable table
- 3- List of detected conflicts
- 4-Track layout
- 5- Velocity route diagram
- 6- Graphical timetable with block occupation and conflicts.

- **Simulation manager:** Nominal or perturbed simulations can be carried out. Nominal (or single) simulation serves normally to check that everything is working fine (some conflicts may not have been detected previously), Nevertheless, further simulations have to be analyzed to emulate real train operations, because of the very complex relationship when a train is delayed (this delay can spread and disturb other trains in the system). These perturbed simulations can be edited according to several criteria (delays in dwell time, accumulated delay at the departure of some trains...). In the case of the perturbed simulations, the program will take into consideration the dispatching methods to reroute the trains. Results about delays, obstructions... are displayed to be considered.



Display of Simulation manager

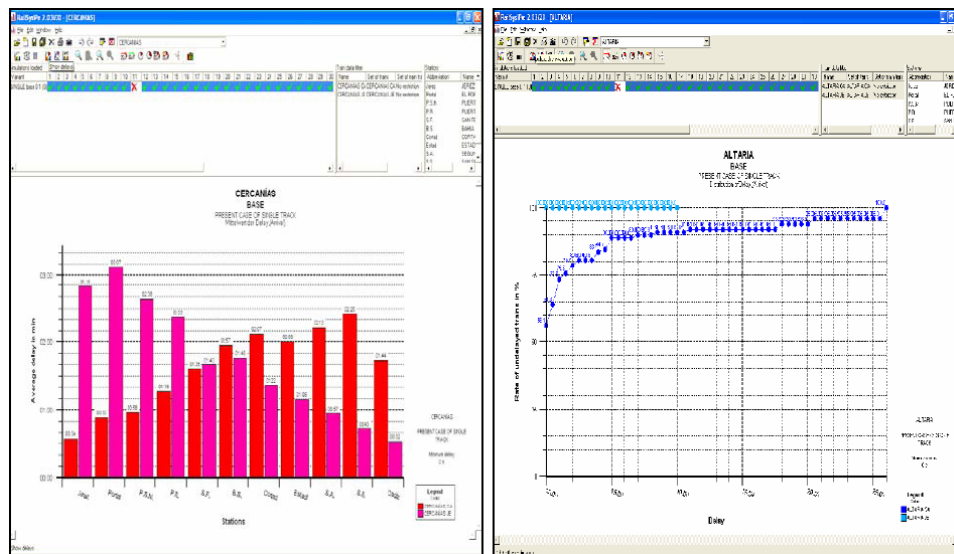
1- Simulation time

2- Delays

3- Current data of a specific train

4- Animated simulated with display of all trains and their delays

- **Evaluation manager (PE):** it has been developed to evaluate the impact of the infrastructure or timetable alternatives. It evaluates the performance of the simulated operational program, by means of preparing and analysing the delay data. To identifying the most favourable option, comparisons should be made. This involves determining whether different options result in significant improvements to the overall system performance.



Examples of statistical evaluation by PE:

On the left hand: average arrival delay of commuter trains in every station

The results can be displayed as performance of the whole network, for lines only, in stations, for the total amount of trains or for different patterns... and different parameters can be analyzed: arrival and departure delays, additionally generated delays (which could identify critical sections), on time running performance at stations, number of delayed trains, number of operational manoeuvres (or rerouting), block occupation...

## 2. DONS

The project DONS (Design Of Network Schedules) was initiated recently by Railned (Railned has the task, amongst others, to advise the Dutch Ministry of Traffic with respect to the capacity of the Dutch railway infrastructure that will be necessary in the future) and Netherlands Railways. The aim of this project is to develop a DSS (Decision Support System), also called DONS, that will assist the planners of Railned and Netherlands Railways in generating timetables. DONS contains two complementary optimization modules which are linked together by a database module and a graphical user-system-interface. The two optimization modules correspond to the two steps of the timetable generation process.

- **CADANS** The first optimization module, called CADANS, assists the planners in generating a tentative timetable based on the constraints deduced from the rough layout of the railway network between the stations, the line system, and the connection requirements at the railway stations. The timetable determined by CADANS is cyclic with a cycle length of one hour. CADANS is being developed by Schrijver and Steenbeek
- **STATIONS** The second optimization module, called STATIONS, assists the planners in solving the problem of routing trains through a railway station. STATIONS considers the stations one by one. The output of STATIONS is a detailed assignment of trains to routes and platforms within the observed station. Such an assignment serves as a local feasibility check for the tentative timetable generated by CADANS. If not all trains can be routed through the station, then STATIONS also points at the blocking trains. STATIONS is being developed by Zwaneveld et al. STATIONS always considers one railway station at the same time. The problem that is solved for this railway station can be stated as follows: Given the detailed layout of the involved railway station, and given the scheduled arrival and departure times of a set of trains, STATIONS aims at routing as many trains as possible through the station, taking into account the capacity of the station, the safety system, and several service requirements. The routing of the trains should minimize the number of shunting operations, and it should maximize the total preference for the platforms and routes. In the problem description a hierarchy of objectives is included. The first objective is to find a feasible route for as many trains as possible. Since we need to comply with the overall timetable, basically all trains have to be routed. However, the problem has been formulated as a maximization problem, because STATIONS should point at the blocking trains if a solution for all trains can not be obtained. Furthermore, if all trains can be routed through the railway station, then the second objective is to minimize the number of shunting movements. A shunting movement is expensive, since personnel (a train driver and assisting personnel) must be allocated. Furthermore, a shunting movement also uses capacity of the railway station, because the routes towards and from the parking area need to be claimed by the safety system. The last objective is to maximize the preferences of the trains for certain platforms or routes. The preference of a train for a certain route mainly depends on the total number of switches in the route, and on the total number of switches in the non-preferred direction.

First the user enters and edits an infrastructure project, using the graphical interface. Next the user defines train services by specifying train type, type of rolling stock, number of trains per hour and the origin and destination station. The system calculates the routing between stations, it derives stopping behavior from the match between type of train and type of station, and it calculates travel times from the type of rolling stock and the route. The user can override any of these calculated values for a specific train service or at a higher default level. The user also specifies connections between train services and other types of relations between services. The problem definition is now complete. Next, the system generates a set of constraints, which represents the problem mathematically. Constraints come from many sources. Travel times (supposed to be constant) and halting times (may be variable), plus possibly a maximum travel time between the end stations (to obtain sufficient quality for express trains), constrain the timetable of an individual train. Headway times limit how quickly trains can follow each other.

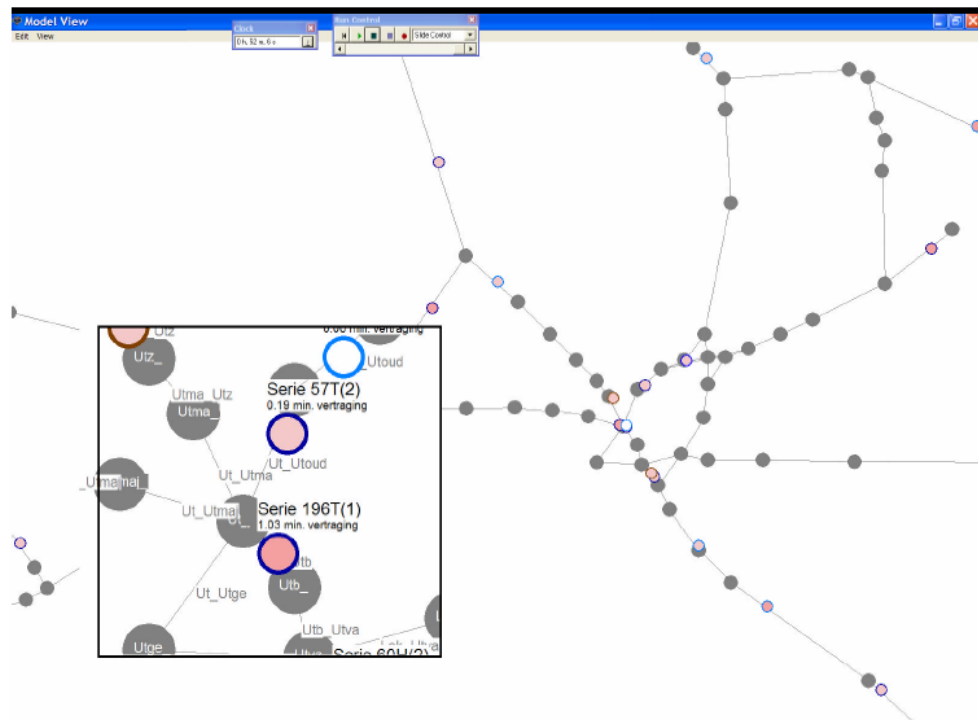
The system also has rules for constraint generation to avoid conflicting movements in large stations; the planner can fine-tune these rules, so that for all junctions and smaller stations a complete set of conflict constraints can be generated. Other types of constraints manage the connections between train series and the deviation of individual trains within a train series of the ideal interval time (e.g. exactly every 30 minutes). The solver module evaluates the list of constraints and then starts to search a solution. If specified, it will drop soft clusters of constraints when necessary; the solution, if available, can be optimized according to weights set by the planner.

The output of the solver is presented in the form of a feasible timetable or as an inconsistent subset of the original set of constraints. Various analysis functions facilitate the interpretation of the output. After the successful generation of a network timetable the planner will want to know if this solution is also feasible for the large stations in the network. At larger stations there are usually many options to route trains and to use platform tracks. At the same time, there are many limitations: buffer time between occupations of track sections should be maximized, some connections should be realized crossplatform, trains in the same direction should start from the same platform etc. The stations solver module tries to route as many trains as possible, while granting as many planners' requests as possible. The output of the solver is a platform occupation diagram and various statistical data on the usage of platform tracks and other infrastructure elements and a list of trains that could not be routed at all. If the solution is not satisfactory, the output may be used to add or relax constraints at the network level (to obtain a new network timetable) or to pinpoint bottlenecks in the station infrastructure. By editing the infrastructure (adding or removing platforms, switches etc.) the planner can study which layout will satisfy the demands. To determine the robustness of the timetable a simulator had to be developed, that was able to study the propagation of small disturbances through the network. Because the modeling of the infrastructure is highly generic and had to be easy-to-change, a template was built for the construction of the DONS-simulator in the Arena simulation environment.

- **SIMONE** (<http://incontrol.nl/files/simone.pdf>) The stability test is performed by SIMONE, Simulation Model for NEtworks. SIMONE is jointly developed by ProRail and Incontrol Enterprise Dynamics. The simulation model is used to judge and test the timetables objectively and to support decision making in a more transparent way. With SIMONE, insight is gained in the sensitivity of the disturbances and knowledge about the complexity of the network is acquired: For example, SIMONE can support:
  - determination of the robustness of a timetable (in how far can a timetable resist disturbances);
  - improvement of the timetable by relating the design standard and the robustness of a timetable in the (simulation) reality;
  - trace and quantification of bottlenecks in a network;
  - analysis of cause and effect relations when delays emerge.

SIMONE is linked to the DONS system in order to generate simulation models of national networks and timetables in an automated way. After generation, these simulation models are instantly ready to use. The next figure shows an example of the animation of a SIMONE simulation model.

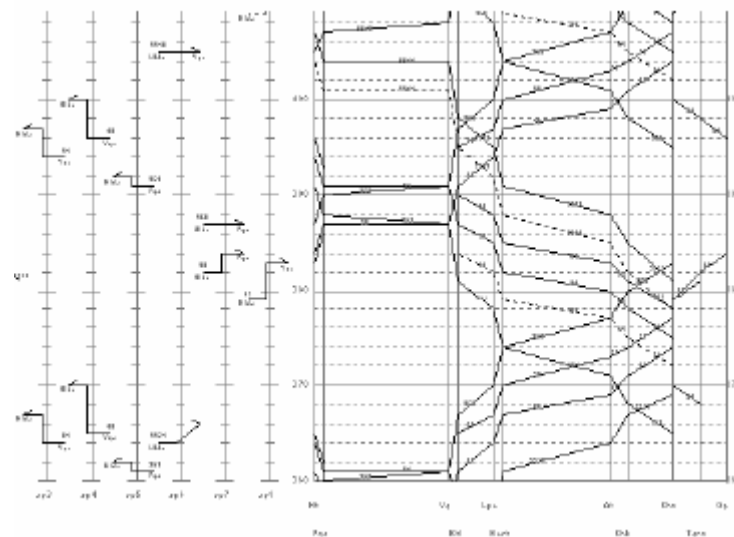




The planner can introduce small disturbances that cause initial delays. He can apply these disturbances to specific trains, train classes etc. The degree of propagation through the network is a measure of the robustness of the timetable. Disturbances propagate only when trains interact. In the DONS-system, some of these interactions are modeled, such as connections between trains and conflicting routes. For simulation purposes, some extra interaction aspects were added to the Timetable Point:

- **capacity:** the maximum number of trains in a Timetable Point. The capacity can be subdivided in groups of platform tracks, which are allocated to specific trains. If no platform capacity is available for a train, it has to wait on an adjacent Connecting Track;
- **conflict-routes:** extra conflict-routes can be defined to model the effect of crossing movements of trains within a Timetable Point.

When the planner wants to test the robustness of a timetable, he selects the timetable and the accompanying infrastructure and constraints from the DONS-database. The system converts these data to a suitable format and stores them in the simulation-database. The planner can also define certain traffic-control rules that have to be operative during the simulation run. These rules are also added to the simulation-database. Now, applying the data-definition of the Arena-template, the simulation model can be generated, including the animation, and the simulation run can be activated. During the simulation the animation of the model can be examined to understand the results from the simulation. This becomes more difficult as the scope of the simulation model expands. Therefore other applications are developed, to visualize the generated output as soon as the simulation has ended. In this way a thorough analysis can be carried out retrospectively. Examples of these visualizations are the time-distance and track occupation diagrams.



*Time-Distance and Track Occupation Diagram –Plan and Realization.*

SIMONE started in 1997 as a research study. The first application of SIMONE was the project Evaluation of Prorail. Next to this, for their final thesis and under the guidance of ProRail Innovation and the Passengers division of Dutch Railways (NS Reizigers), four students have researched fundamental issues such as the relationship between the amount of slack in the timetable and the length of the stretch. Currently, ProRail and the Passengers division of Dutch Railways use SIMONE. In the future, these organisations will use SIMONE more and more for supporting their decisions on planning, design and usage of the network. The concepts are suitable for the approach of similar problems. Expansion possibilities of SIMONE are the connection with other timetable systems and the detailed modelling of track layouts at the station yards.

### 3. PETER

PETER (Performance Evaluation of Timed Events in Railways) is an analytical tool based on a (system-theoretic) max-plus algebra performance evaluation approach. The railway model and a first prototype has been introduced at COMPRAIL 2000. Based on this experience, Delft University of Technology decided to cooperate with ORTEC to develop a userfriendly decision support system for railway planners. PETER now combines state-of-the-art efficient mathematical algorithms with a graphical man-machine interface that suits railway planners. PETER quickly assesses network performance indicators in a deterministic setting corresponding to the design times used in timetable construction. A timetable represents the steady-state according to which trains should operate. Timetable performance is then analysed as the effort of returning to the steady-state after disruptions. Systems of interconnected train services have a special structure that can be described by  $(\max,+)$  recursions, resulting in a linear system in max-plus algebra. Efficient algorithms have been developed to analyse such systems in real-time. Performance indicators include cycle times, throughput, and stability margins, which are related to critical circuits (Bottlenecks) in the train network. Timetable robustness is analysed by cumulative recovery times and delay propagation. The tool contains the following functionalities:

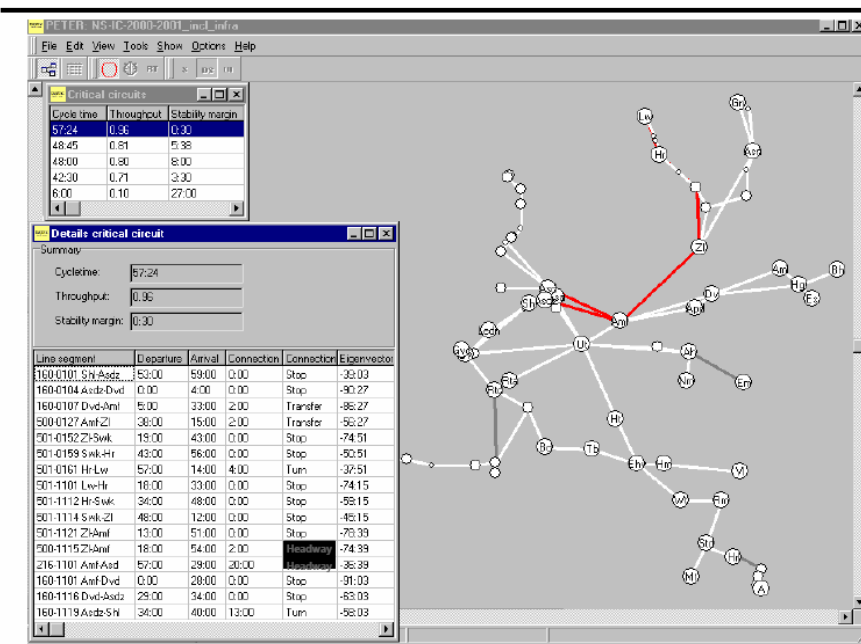
- data import and automatic model building,
- data view and editor,
- analysis computations,
- results view and network
- data and results export.

Networks can either be created using the build-in editors or imported from ASCII input files with a prescribed format. A *generic data* input file contains information on stations, train lines, and connections, and is easily generated by standard text editors or spreadsheets. After reading the input data, PETER automatically constructs the max-plus model and draws the network view. A build-in editor can also be used to edit data. After editing a feasibility check follows and a new max-plus model is constructed. Edited or manually inserted networks in PETER are also saved in the generic format. The modular system architecture of PETER enables easy extension of functionalities. As an example, a module is provided that directly imports data files from the Dutch timetable design tool DONS [3]. Another envisaged extension is a direct access link to the DONS Data Market [9], by which railway planners at Railned or NS Reizigers can apply PETER directly with the full functionality of DONS.

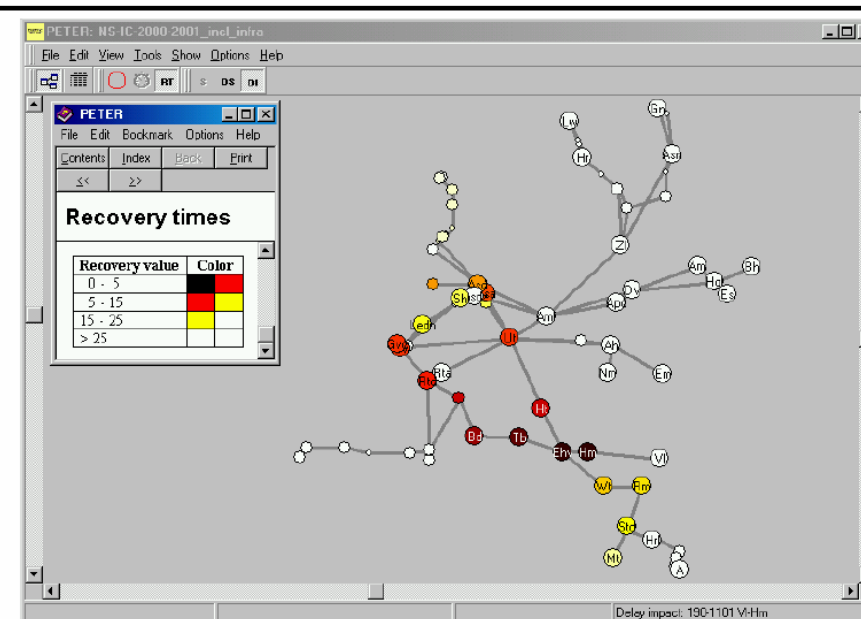
The delay propagation module requires a set of initial delays, which can be inserted manually or imported from a *delay file*. Manually inserted initial delays can also be saved to the standard delay file for future usage. The delay files enable easy access to a range of scenarios for delay propagation. In the menu Tools the analysis computations are activated. A disabled computation item means that computed results are still valid. In the Tools menu the user can also choose to include or exclude all transfer times. A toggle denotes the current status. By excluding transfer times the situation is analysed where transfer connections can be cancelled, the so-called *controlled* network. The analogue holds for layover times. Excluding layover times presumes that reserve trains are available when necessary or that train circulations are not fixed to train line routes.

Results can be shown in tables, visualized in the network (see Section 5), and saved in output files. Also the constructed max-plus model can be saved in an output file.

## IC network: Critical Circuit



## IC Network: Delay Impact 1900 VI-Gvc



### Conclusions

- PETER is a software tool based on max-plus algebra to help railway planners
- PETER computes **network performance indicators** for evaluation and comparison of timetable structures
- **Bottlenecks** (critical circuits) with the tightest schedule are identified
- **Robustness to delays** through buffer times are clearly detailed by recovery times
- **Delay forecasting** by propagation of initial delays over time and network
- PETER gives results of **large-scale networks** in **real-time**

#### 4. ROMAN

(<http://www.ilog.com/download/docs/SS-Siemens-RailRoad2002.pdf>)

ROMAN (ROute MANagement, this is used in Germany and Austria) store information on track topology, engine and coach properties or available crews in databases. Thus, the running time of trains can be calculated in advance. Graphical user interfaces enable schedule planners to construct or edit schedules interactively based on time space diagrams. Conflicts (like missing headway) are automatically indicated on the screen. After the generation of a schedule, simulations can be performed.

The system takes the arrival and departure times of trains and generates on-screen graphs that show the interplay among the vehicles. ROMAN lets the operator quickly spot conflicts in schedules and resolve them to improve the flow of traffic.

ROMAN is currently based on CAD and simulation methodologies without supporting optimization. The analytical examination of timetable planning is supported by the mentioned characteristics such as infrastructure topology, block sections and running time calculation in the planning process as well as reports providing capacity relevant data for a desired route. The computer aided design tool can support the conflict detection but not yet automatic resolution. In practice, often capacity data is obtained for mature timetables rather than for early conceptual studies, but it is also possible to use the tool for studies early in the planning process, because at this stage the definition for timetable planning can be coarser than for simulation. The timetable data then can be passed to the simulation module (and vice versa) where finer analysis and the stability of the timetable can be assessed. It is possible to put exceptions such as track closures, speed reductions or disturbances (either random or defined) into the system and simulate their effects on the timetable. The results are presented in graphical and tabular outputs and this can help to study the so-called robustness of the designed timetable. Disturbances and other contingency events can be particularly derived from historical analysis of recorded trends and service performances on the specified line. These can be due either to the Infrastructure Manager or the Transport Operators (e.g. infrastructure or rolling stocks reliability rates, breakdowns and resolution times).

## 5. VIRIATO

([http://www.sma-partner.ch/vp/viriato\\_s.php?id=10&lang=e](http://www.sma-partner.ch/vp/viriato_s.php?id=10&lang=e))

VIRITATO (developed by SMA and Partner, 2001) is mainly used for strategic planning purposes, i.e. adapting infrastructure to future service concepts and coordinating several operators or products sharing the same infrastructure. Planning regular interval trains is a main concern, but there are also options for analyzing single trains, e.g. freight freeways, and it allows the user to determine the level of saturation of a specified line, in percent. A new module that compresses a given timetable, allows for determining the saturation rate of a line or a part of a line, as a percentage. This method leads to varying results for a same line, depending on the considered section's length.

A netgraph is the schematic representation of a railway network and timetable. Each combination of time-coordinated trains appears in the netgraph as a bar connecting the stations and hubs served. With a netgraph it is possible to represent all lines of a network and their mutual relationships (e.g. connections between trains in hubs). Viriato is the first planning tool to succeed in combining the netgraph, the train diagram and the timetable in a tabular form.

- Displaying regular interval trains in form of a multicolor netgraph (size up to format ISO A0) according to the standards and conventions of the regular interval timetable,
- Selecting and editing trains within the netgraph,
- Simple drawing facilities to enhance netgraph layout (legend, remarks etc.).

At the moment the following add-on modules to Viriato are available in addition to the standard version:

- **CALENDAR**

In the long-term service planning, standard day types are sufficient for the definition of the services. For the short-term service planning, on the other hand, a precise definition of the timetable is vital.

The add-on module Calendar enables a precise validity definition for trains, specifying exactly on which day a train is running. In a validity period, typically a timetable period, the following definitions are possible:

- Definition of public holidays (Easter, bank holidays, etc.),
- Definition of no service periods (e.g. school holidays),
- Definition of additional running days and no service days,
- Definition of reduced validity periods within the timetable period.

Furthermore, the add-on module Calendar includes the following functionality:

- Display of graphic and customer timetables, arrival/departure tables and netgraphs for a single calendar day,
- Calculation of train kilometres based on a real calendar year instead of a norm year,
- Precise calculation of the number of departures at a station,
- Assignment of different validity definitions to interval trains of a train family,
- Validity changes within the train route.

- **LINE MAP**

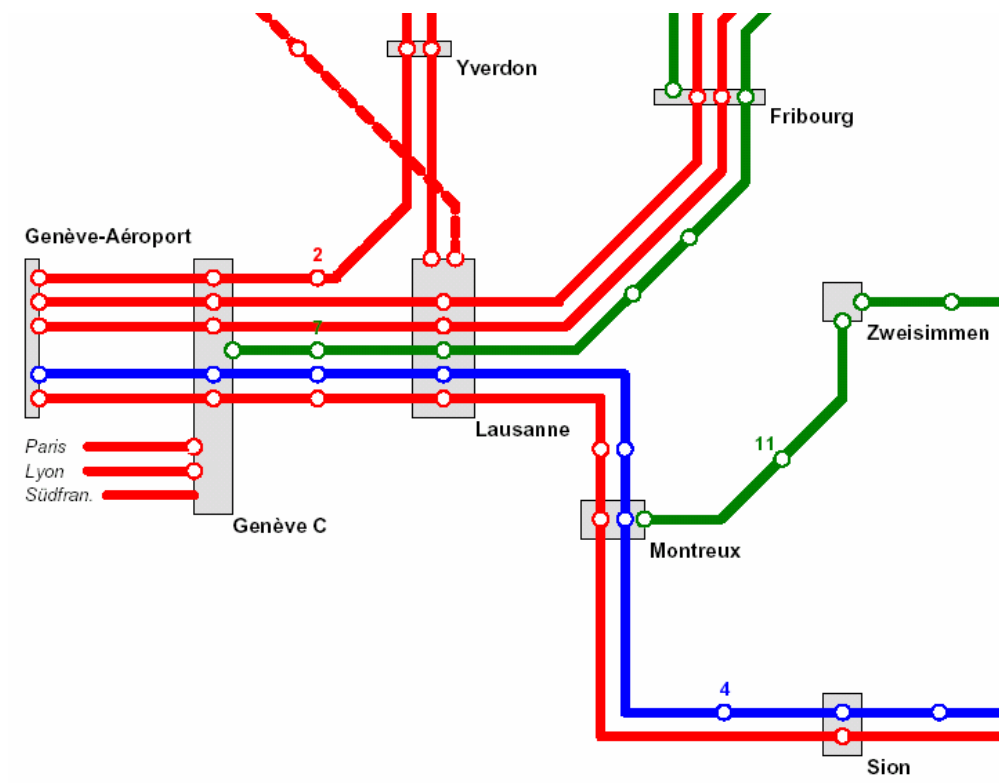
A convincing communication and visualisation is essential for a successful service concept on all levels of planning (short-, medium- and long-term). A service concept is usually illustrated as a netgraph, which provides the display of the net-wide coherence between services on one sheet of paper.

Because a netgraph contains a lot of details, getting a quick overview or making a comparison of different variants is hardly possible. As far as medium- and long-term planning is concerned, the arrival and departure times pretend a precision not existing.

The line map addresses these drawbacks of the netgraph by providing a concise and easy-to-create alternative.

The module Line Map offers the following functionality:

- Easy-to-read representation of service concepts for presentations and reports,
- Comparison of alternative service concepts,
- Illustration for commercial documents, e.g. as a graphic help for the customer timetable.
- As the line map is based on existing netgraphs, no additional effort is required for the production of a different representation.



#### • TRACK/STATION OCCUPATION

Stations are often the focal points of a railway network. Lines come together, trains are arriving and departing, passengers are boarding the trains, and last but not least, trains are parked, cleaned and maintained.

Stations can also be bottlenecks within an existing or future network. Therefore, timetable planners need to examine the track usage and platform occupation for any timetable they compile. Depending on the planning phase, the display of the platform occupation must fulfil different requirements:

- Essential for long-term-planning is the identification of future demands of tracks and platforms.
- Developing next year's timetable needs to go hand in hand with the track allocation.





## • ROSTERING

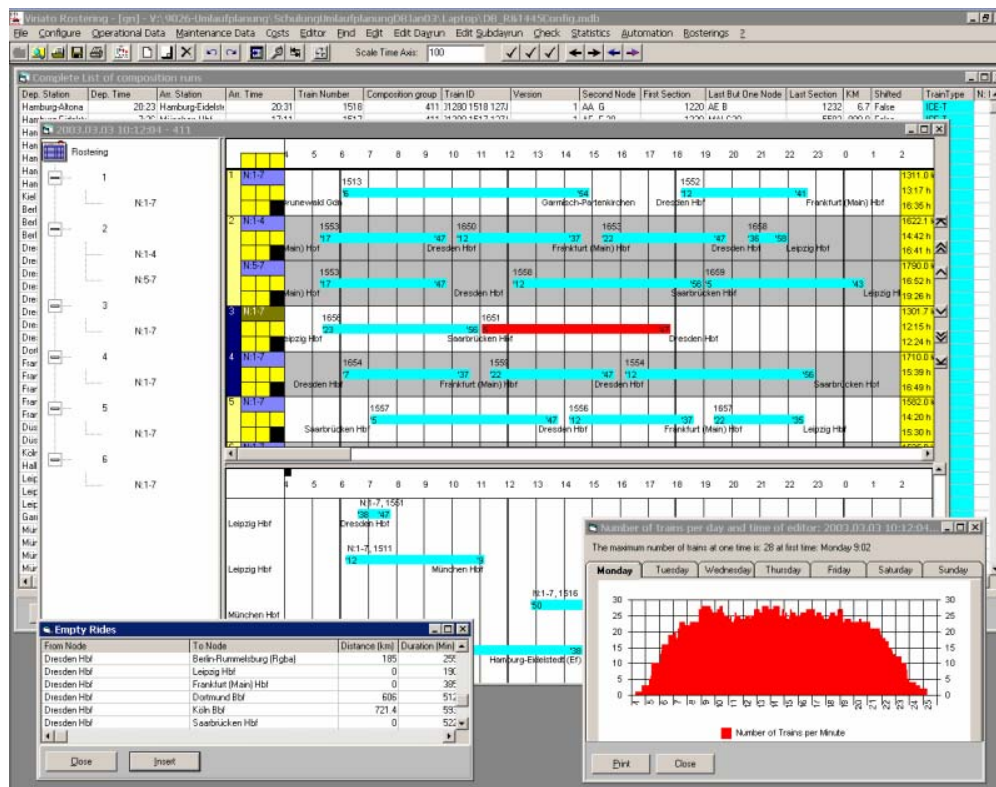
Viriato Rostering includes a simple, easy-to-use graphical editor, enabling the user to create roster diagrams manually or automatically. The definition of various maintenance tasks is part of Viriato Rostering, as well as the comprehensive consistency checks.

On all levels of the timetable planning (short-, medium- and long-term) the planning of the services and the rostering of the rolling stock occurs simultaneously, in order to determine the most important cost factors for the operator.

The following functionality distinguishes Viriato Rostering:

- Detailed operational data (turn-around times per node and composition, reversing a train),
- Definition of any maintenance task (depending on rolling stock or interval), assignment of maintenance tasks to nodes,
- Definition of empty rides,
- Any combination of cost units (per km, per maintenance task etc.) in cost functions,
- Intuitive editor with undo function, context menu, function tree for navigation, search function for fitting next rides, moving of rides with drag-and-drop,
- Comprehensive checks (transfer in the same node, turn-around times, maintenance tasks).

Together with the cost functions, the planner is supported by various statistical evaluations in the problem analysis and the assessment of the roster diagrams.



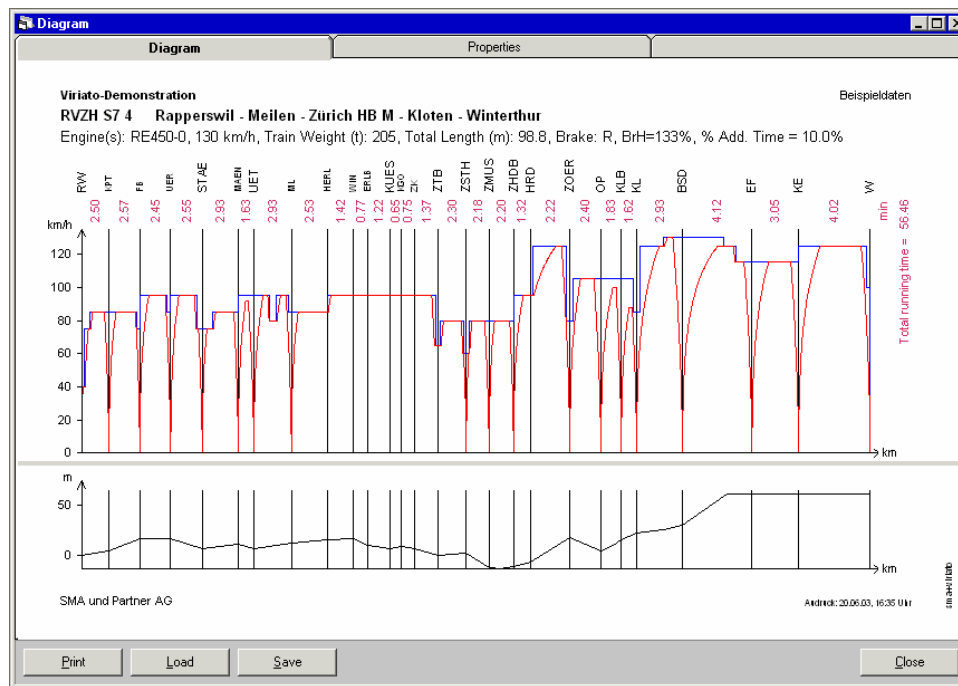
## • RUNNING TIME CALCULATOR

The add-on module Running Time Calculator enables the user to do precise planning. It offers the definition of several speed profiles for the same infrastructure, and the calculation of the resulting running times for different train configurations.

The running time calculation module includes a library of numerous European engines with their tractive effort diagrams. Additionally, the user has the possibility to define any other engine of choice.

Thereafter, the calculated running times can be easily transferred to Viriato, thus refining the service planning. The running-time calculator is available as an add-on module to the standard version of Viriato, including the following functionality:

- Precise calculation of running times for any train route and any train configuration, taking into consideration changes of the train configuration (e.g. strengthening or alighting trains),
- Definition of various speed profiles (e.g. conventional or tilting) with automatic reverse function,
- Node and track specific speed values for incoming and outgoing trains in stations,
- Consideration of gradients as well as tunnel and curve resistances,
- An extensive and expandable set of various engines,
- Visualisation of the running time as a diagram with speed limits, train speed and elevation profile,
- Calculated running times can be easily taken over into the train schedule.



## • TRIP TIME ANALYSIS

The Viriato module Trip Time Analysis supports the planner in the assessment of questions concerning the timetable and service quality. The module calculates from the data of a timetable alternative all convenient relations in the network, considering the running time and the transfer time. Thereof important key figures may be calculated, characterising a timetable alternative from the market point of view.

For a selection of origins and destinations, and a defined time slice, the following calculations may be computed:

- Connections with shortest trip time, with least changes and with best connection value
- Display of 24 connection criteria (e.g. Trip time, waiting time, distance, speed) in tabular and matrix format.
- Manifold sorting and filter possibilities within the tables and aggregation of the results.
- Comparison of two time table variants
- Export to GIS and possibility to weight the results with demand data.

**Travel Times**  
Display columns Variant

Matrix: Variant  
Table: Variant  
Matrix: Base  
Table: Base  
Matrix: Compare  
Table: Compare

Origin	Destination	Best traveltime	Var. Best traveltime	Diff. Best traveltime	Best changes	Var. Best changes	Diff. Best changes	Best waiting time	Var. Best waiting time	Diff. Best waiting time	Best km	Var. Best km
Andelfingen	Hinwil	77	76	1	3	3	0	21	26	-5	55	65
Andelfingen	Präfikon SZ	92	91	1	2	2	0	23	24	-1	80	80
Andelfingen	Regensdorf-Walt	73	72	1	2	2	0	17	18	-1	57	57
Andelfingen	Uetikon	56	55	1	2	2	0	9	10	-1	52	52
Bauma	Dietikon	88	83	5	1	1	0	18	8	10	61	61
Bauma	Oberglatt	80	82	-2	1	1	0	6	6	0	72	72
Bauma	Regensdorf-Walt	78	78	0								
Dietikon	Bauma	90	82	8								
Dietikon	Hinwil	65	52	13								
Hinwil	Andelfingen	75	76	-1								
Kloten Balsberg	Bauma	88	80	8								
Oberglatt	Bauma	81	82	-1								
Oberglatt	Präfikon SZ	60	57	3								
Präfikon SZ	Andelfingen	92	92	0								
Präfikon SZ	Oberglatt	61	56	5								
Regensdorf-Walt	Andelfingen	72	73	-1								
Regensdorf-Walt	Bauma	79	79	0								
Uetikon	Andelfingen	56	57	-1								
Total		18	1363	1323	40							

**Travel Times from: Andelfingen (85AN) to: Uetikon (85UET) Output of all res**

ID	ID Dep Station	Dep. Station name	Dep. Time	ID Arr. Station	Arr. Station Name
1	85AN	Andelfingen	8:05	85W	Winterthur
1	85W	Winterthur	8:22	85ZSTH	Zürich Stadelhofen
1	85ZSTH	Zürich Stadelhofen	8:44	85UET	Uetikon
2	85AN	Andelfingen	8:05	85W	Winterthur
2	85W	Winterthur	8:37	85UET	Uetikon
3	85AN	Andelfingen	9:05	85W	Winterthur
3	85W	Winterthur	9:22	85ZSTH	Zürich Stadelhofen
3	85ZSTH	Zürich Stadelhofen	9:44	85UET	Uetikon

Show/Print connections  
☐ Best connection  
☐ Fastest connection  
☐ Minimum changes  
☐ Good  
☒ Reasonable

Excel Close

The following add-on modules, actually in development, will enhance and extend the functionality of Viriato:

- Automatic analysis of the transfer times within nodes and hubs between the lines to evaluate the service quality
- History-based infrastructure data for planning in multiple time horizons

VIRITATO is at least used in former Czechoslovakia, Denmark, the U.k., Portugal, France, Finland, Italy and Estonia.

## 6. CAPRES

([http://www.sma-partner.ch/vp/usertagung/5\\_CAPRES\\_E.pdf](http://www.sma-partner.ch/vp/usertagung/5_CAPRES_E.pdf))

([http://www.fasta.ch/capres/capres\\_english.htm](http://www.fasta.ch/capres/capres_english.htm))

CAPRES has been developed by the Laboratory of Intermodality, Transport and Planning (LITEP) of the Swiss Institute of Technology Lausanne (EPFL) in collaboration with the Swiss Federal Railways (SBB). It is a future module of VIRIATO. CAPRES is a model for the elaboration and saturation of timetable variants. The model takes into account the rail network and determines by iterations, all available extra trainpaths, given all the constraints and interconnections between lines. CAPRES takes into account junctions and station characteristics, and determines capacity on a railway network, not just in a single line. It is used in Switzerland, France, Italy and the U.K.

The traditional network and operational data have to be completed with the information about where, when and how the network capacity must be used.

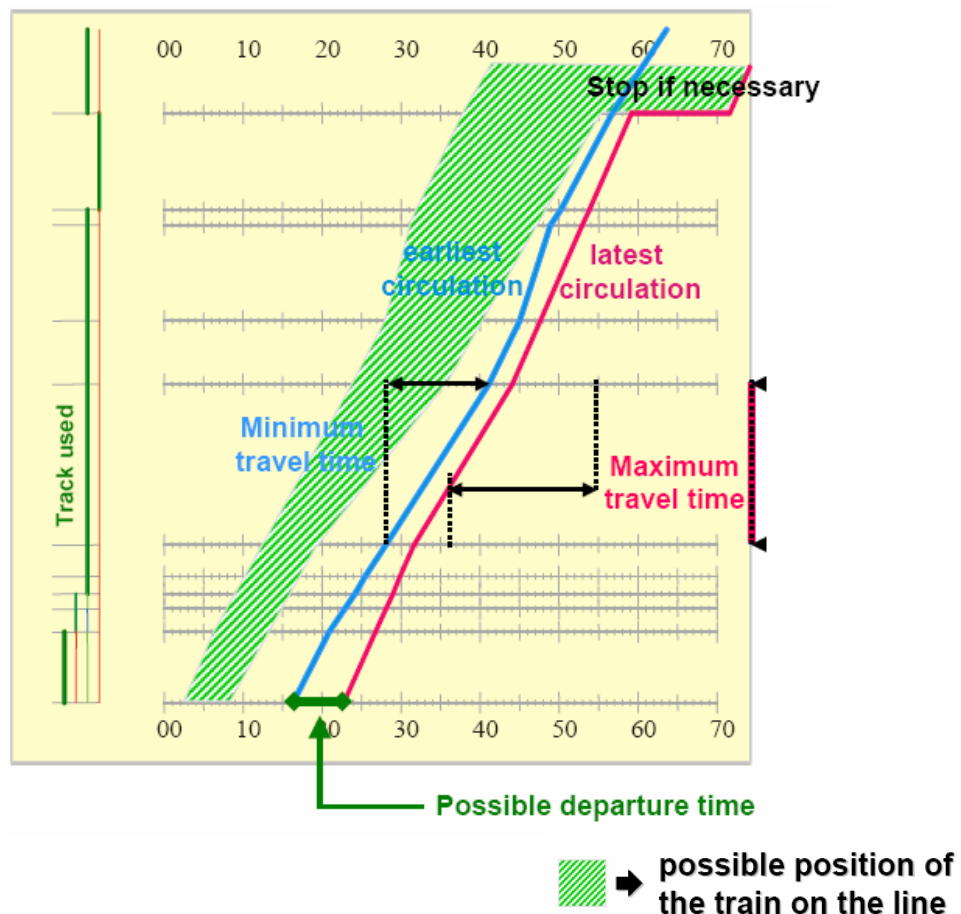
The saturation strategy defines for each origin-destination couple in the network:

- The train categories and their operation,
- The number of trains,
- Their priority concerning the network capacity use.

CAPRES evaluates the use of the capacity as the number of extra trains that may run on the network, complying with the saturation strategy defined by the operator, and the constraints applicable in the network.

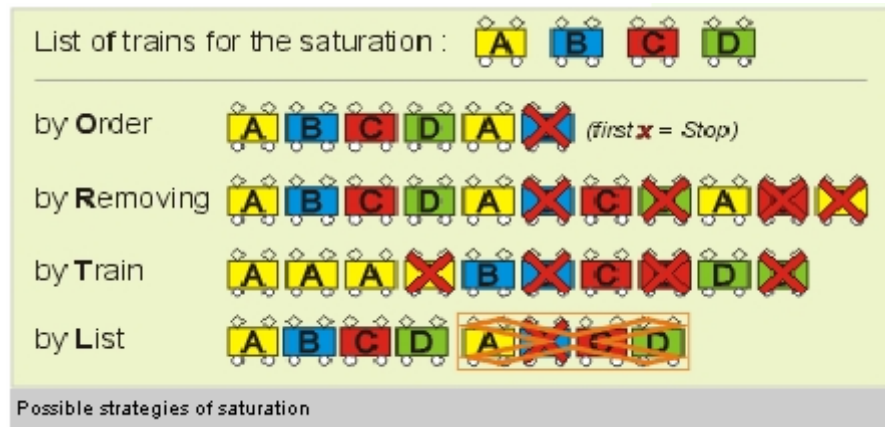
Definition of the trains used to saturate the timetable:

- Itineraries and tracks used for each network section
- Minimum and maximum travel time for each section
- Acceptable stop time
- Arrival and departure time for one or several stations
- Category and type of train



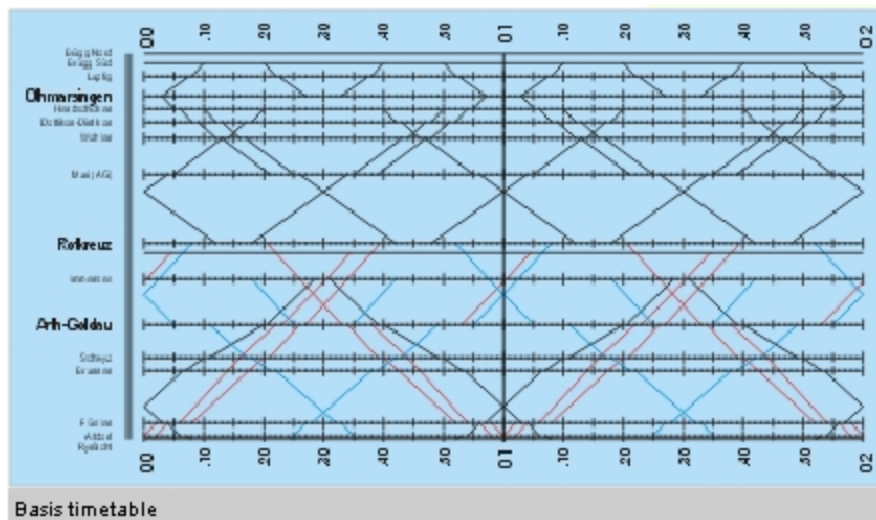
Track occupation and conflicts are automatically solved during the elaboration and saturation. The resulting timetables are free of conflicts.

Saturation consists in the elaboration of a new timetable, based on a basis timetable, by adding the most possible train-paths, with regard of predefined constraints. The order of new trains added to the timetable depends on the saturation strategy. Consequently, it defines priorities among extra trains or among groups of extra trains.

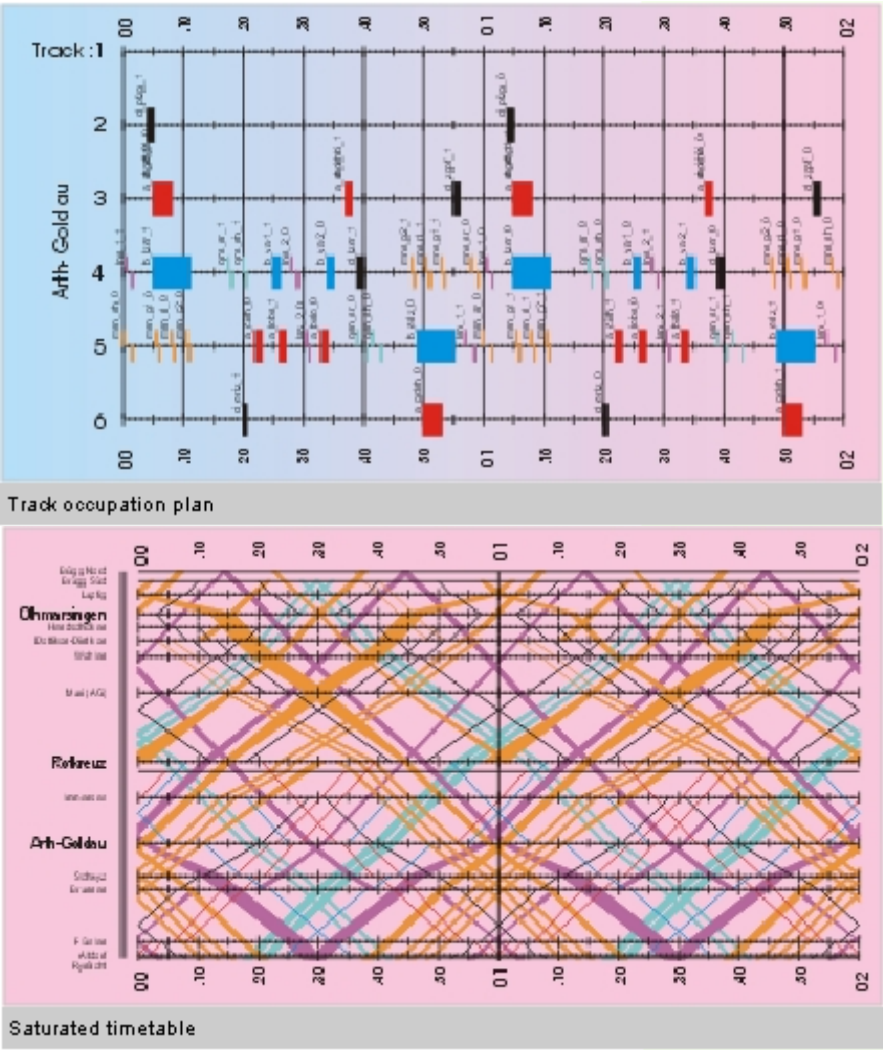


#### Typical Studies:

- Assessment of the unused capacity of a network
- Capacity bottleneck detection
- Capacity comparison of different timetable structures
- Impact of new lines added to a network
- Design of timetable variants
- Estimation of the effects on capacity caused by modifications of infrastructure, rolling stock and operation parameter.
- examination of the feasibility of a given timetable for the network







## 7. CAPACITY

CAPACITY is a computing tool developed by the infrastructure division of SBB for internal needs in order to be able to quickly analyse different long term scenarios and to determine bottlenecks for the whole Swiss railway network. This "Excel"-sheet is based on formula of the UIC, which take into account general characteristics of lines, the number and the mix of trains, to calculate the capacity section by section and thus to determine which section are saturated. Based on a line capacity calculation, it partially takes into account network effects by using a factor that limits the calculated capacity near junctions.



## 8. FASTA

(<http://www.fasta.ch/>)

FASTA is a comprehensive software package for the simulation of trains running on a network and timetable stability analyses.

It has been developed to analyse the behaviour of the timetable structure on a network scale. FASTA points out the evolution of delays and their geographic distribution. It uses a database describing infrastructure and timetables of the different lines.

The software has been developed by the Laboratory of Intermodality, Transport and Planning (LITEP) of the Swiss Federal Institute of Technology Lausanne (EPFL), in cooperation with the Swiss Federal Railways (SBB).

FASTA has been designed to:

- identify and analyse delays on a network level,
- detect causes of delays,
- show the geographical distribution of delays.

The software provides the user with the following outputs:

- delay diagrams with regard to the importance of the different nodes, different lines and different train categories,
- geographical delay diagrams for each hour of operation.

FASTA is based on the following concept:

- it's an event controlled discrete simulation tool, events being arrival and departure of trains in nodes,
- FASTA simulates a timetable operated on a given network, on the basis of the description of network (lines and nodes) and trains,
- the simulation takes into account network specific constraints, such as minimal headways and connections between trains at stations,
- FASTA runs in deterministic mode (running times of trains are set) or in stochastic mode (running times of trains are taken from a running time distribution function),
- inputs and results are stored in specific databases and may be exported.

The rail network is modeled using the classical graph theory concepts. Nodes are stations in the network and arcs are sections between stations. Each section has a specified number of physical tracks. A physical track section has a parameter defined which specifies the direction of traffic movement allowed for the track. Routes of trains are modeled as paths in the graph which consists of a sequence of sections in the network. The exact routing of the trains is determined dynamically during simulation of train-runs.

The model includes the following station types:

- connection stations: connections between trains are modeled,
- stop stations: stations where trains stop,
- crossings: points in the network where routes of two lines intersect,
- virtual stations: used for modeling network details and exceptions.

A network section is made up of physical tracks and is modeled using the number of physical tracks that it is made up of and the directions of traffic that each track is capable of handling. All trains which perform the same service are grouped in train-families.

The timetable consist of arrival, departure and through times of all trains entered into the system. Using the timetable information, the model generates a train connection list based on a simple set of expert rules

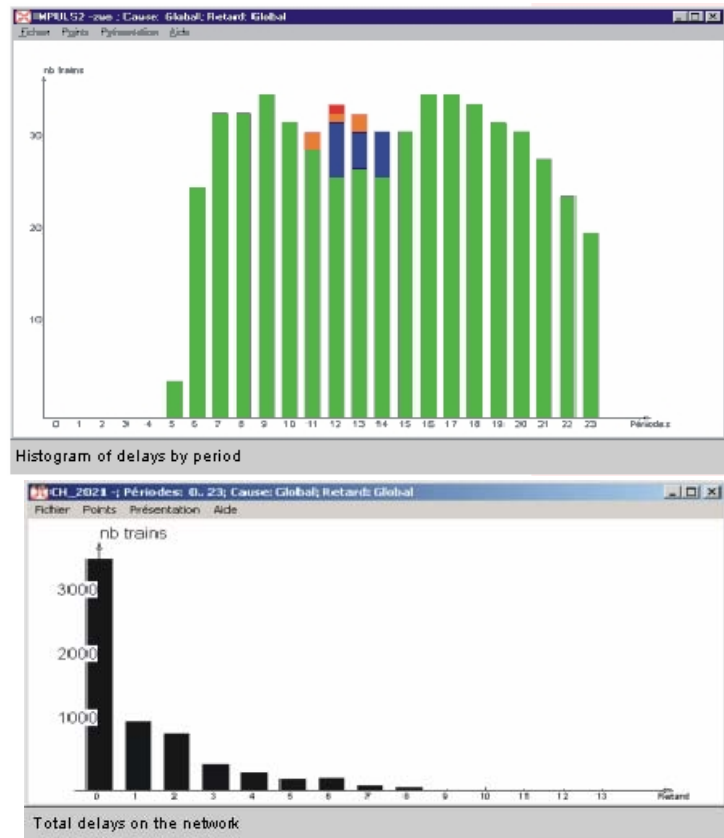
The model generates a rotation plan similar to connections except that the rules are simpler. According to a traffic control policy set by the timetable planner, trains wait for their connections.

FASTA provides two types of results:

- global statistical results depicted as graphs,
- detailed alphanumerical results.

The global statistical results allow a fast analysis of the system functioning in order to detect critical zones and periods for stability. Results are mainly depicted as delay histograms:

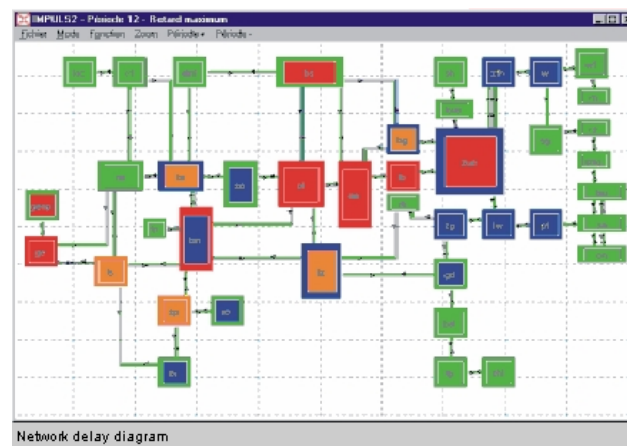
- histogram of delay in a node for several periods,
- histogram of delay for a period in several nodes,
- histogram of delays for all sections.

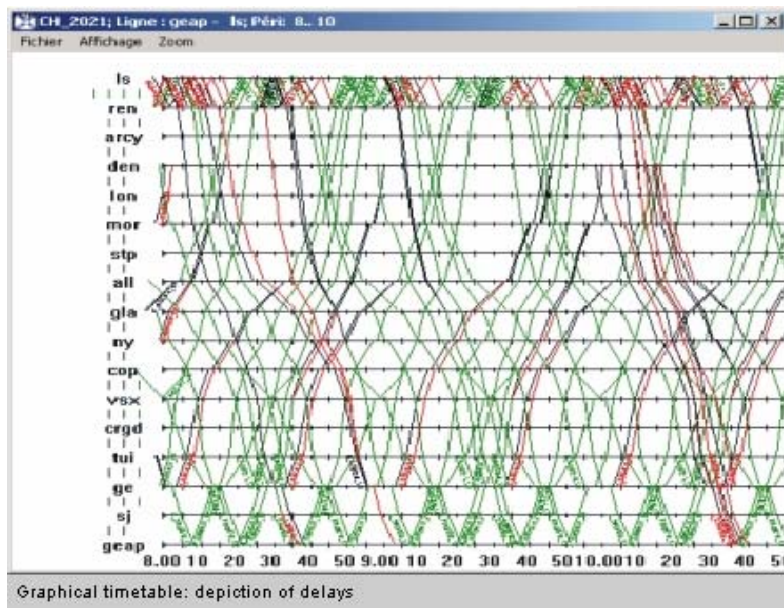


The model permits as well a graphical visualization of the evolution of delays in the whole network. This visualization includes the following representations of delays:

- for each section,
- for arrival at the node,
- for departure at the node.

Delays are represented in form of a delay function which are generated during the period under consideration. Those functions could be: delay maximum or minimum, average delay, most or least frequent delay.





The detailed alphanumeric results permit detection of critical zones for the emergence, aggravation and propagation of delays in the network. These results allow an even more in-depth analysis of delay evolutions in the different zones.

Nd	Arrivée réelle	Arrivée hor.	Retard	Départ réel	Départ hor.	Retard
lgut	08:55.0	08:51.0	4.0	08:55.0	08:51.0	4.0
bnwf	08:56.4	08:52.5	3.9	08:56.4	08:52.5	3.9
bn	08:58.6	08:55.0	3.6	09:05.0	09:05.0	0.0
bnwf	09:07.5	09:07.5	0.0	09:07.5	09:07.5	0.0
wkds	09:08.5	09:08.5	0.0	09:08.5	09:08.5	0.0
wkd	09:09.0	09:09.0	0.0	09:09.0	09:09.0	0.0
ost	09:10.0	09:10.0	0.0	09:10.0	09:10.0	0.0

Detailed result of train simulation

FASTA is used to evaluate rail timetables. It can be of help with the :

- analysis of the stability of a cyclic timetable under a stable or disrupted regime,
- comparison of different traffic control policies,
- analysis of the consequences of maintaining connections on the timetable stability,
- fixation of running time buffers as well as their geographical distribution which are needed to guarantee timetable stability,
- analysis of track maintenance effects on the timetable stability of the network.

The results provided by the FASTA model help in the statistical macro-analysis of delays in the network as well as in the detailed analysis of delays and their causes. The main results are:

- delay histograms shown by delay-causes, timetable periods or by importance, in a node, on a line, in the network, for one or more train categories,
- geographical distribution of delays in a region or for the entire network,
- development of this distribution in the network on an hourly basis,
- a detailed evolution of the functioning of the network over time.

## 9. AFAIG

([http://www.fasta.ch/afaig/afaig\\_english.htm](http://www.fasta.ch/afaig/afaig_english.htm))

AFAIG is a comprehensive software package for the planning of layout and operational plans of major railway passenger stations.

The programme has been designed to:

- evaluate extension and modernization projects of the fixed installations;
- develop new operational strategies and timetable structures;
- develop peak time timetable;
- elaborate temporary timetables during traffic disturbing construction activities;
- analyze periodic adaptation of timetables.

AFAIG uses a database describing infrastructure, rolling stock, operation rules and timetables. The programme offers ample possibilities to its users:

- compute running times of trains;
- assist the planner to construct an optimal occupation chart for large railway stations;
- allocate each train appropriately and efficiently;
- optimise conditions of connecting trains;
- minimise risks of conflicts between trains and shunting movements.

The software has been developed by the Laboratory of Intermodality, Transport and Planning (LITEP) of the Swiss Federal Institute of Technology Lausanne (EPFL), in collaboration with the Swiss Federal Railways (SBB).

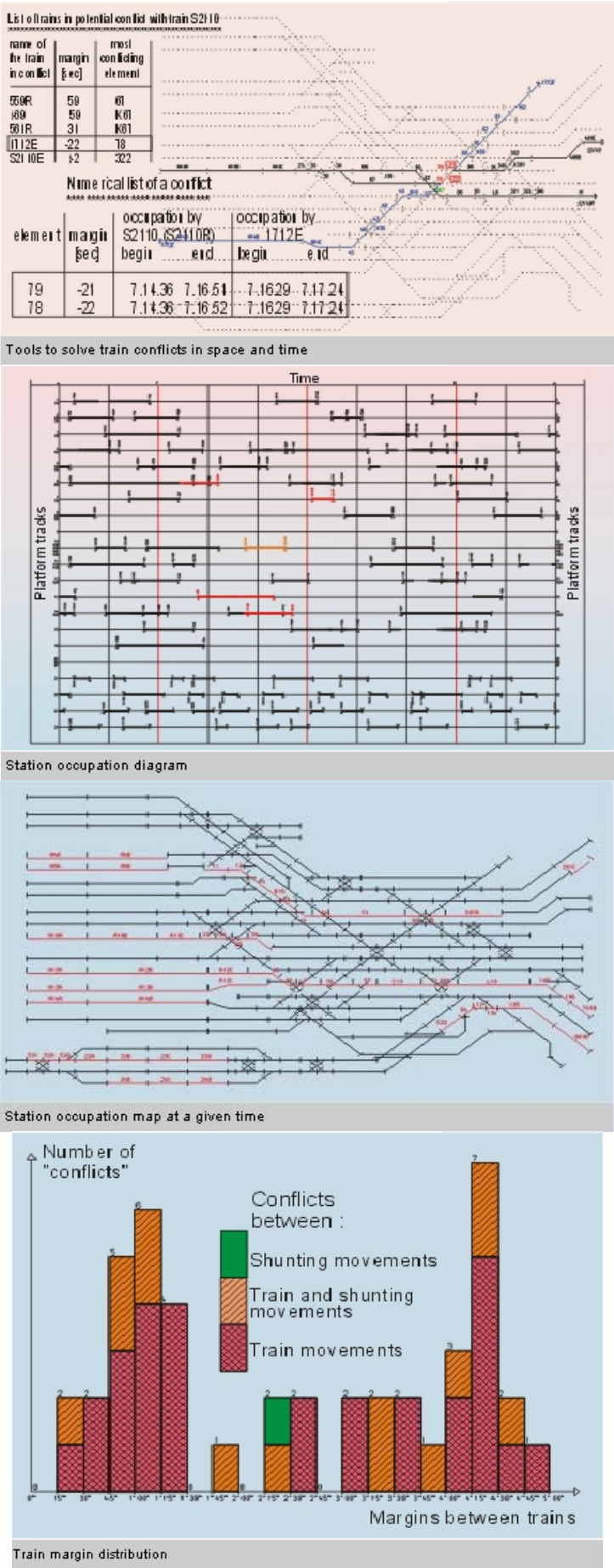
A fully interactive and graphic tool for planners and schedulers, AFAIG manages data on track layout, safety installations, rolling stock and movements in the station and on its access lines. In a conversational mode, AFAIG lets the scheduler place train movements, after which it calculates the occupation time of the successive sections for each itinerary, detects and measures the conflicts between movements, verifies that all the operational constraints are respected and takes care of tedious drafting tasks. Relieved of the operations that can be automated, the planner for a major railway station can devote his time effectively to the tasks of design, analysis and multi-criteria evaluation.

The model uses the following components to describe the system:

- the track network, its layout and speed limits;
- the safety installations;
- the rolling stock;
- operation schemes.

The model provides the user with values of different performance measures for the evaluation of operation programmes which he has developed. These are:

- occupancy rates of platform lines and route elements;
- histograms of margins between trains, which gives a global indication of timetable ;
- list of margins between trains, which is used to identify the trains most prone to delay;
- statistics of train assignments by direction.



## 10. DEMIURGE

([http://recherche.sncf.com/uk/projets/uk\\_demiurge.html](http://recherche.sncf.com/uk/projets/uk_demiurge.html))

Démiurge is a software program designed to assist in making rail network capacity studies. It is currently being used by SNCF Engineering. This software can:

- evaluate a network's capacity to absorb additional traffic
- locate bottlenecks
- assist in making decisions about infrastructure investments
- optimise current and future timetables
- calculate the residual capacity of a timetable

The user described the network to be studied after determining the required level of detail and setting the operational constraints:

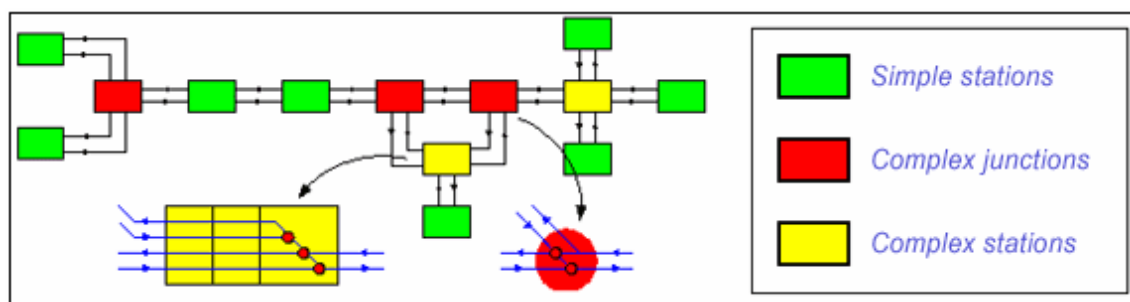
- headway times on open tracks
- intervals between conflicting routes at nodes (stations or junctions)
- platform re-occupation times

The network to be studied can be an existing network or a future one. The network model contains the following technical constraints:

- The line sections: The expert defines each track (one-way or two-way), with its headway time.
- The nodes: The nodes can be described with the level of detail required.

They can be:

- Simple nodes: The constraints are not listed
- Complex junction nodes: The expert defines the routes, and the time intervals between conflicting routes.
- Complex station nodes: The expert defines the routes, and the time intervals between conflicting routes and the platform re-occupation times.



Trains were divided into three sub-groups:

- Imposed trains: existing trains or trains that must be scheduled
- Future trains: trains required by the Passenger or Freight Divisions in the short or medium term (1 to 3 years)
- Saturation trains: theoretical trains to meet long-term requirements (5 to 10 years)

The train model includes commercial constraints:



- The routing description: list of nodes, tracks and platforms.
- The arrival and departure times at the nodes.
- The stopping time in stations (min, max).
- The basic interval timetable constraints.
- The maximum limit of journey times.
- The correspondence links (min, max).
- The minimum time between two trains with the same stopping-pattern.

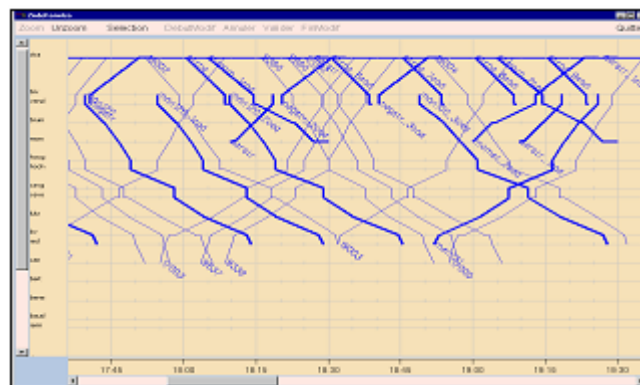
The problem to be solved is a constrained optimisation problem. DEMIURGE is based on a mixed linear integer programming solving algorithm, and can use either an exact method or an approximate method by decomposing the problem into interdependent subproblems. DEMIURGE computes the departure and arrival times of the trains in nodes. The goal is to find the best solution, which:

- maximises the number of future and saturation trains inserted in the timetable
- minimises journey, stopping and connection times
- minimises changes to imposed train timetables (if authorised)
- minimises infringements of technical constraints (if authorised)

The user is offered numerous parameters for conducting different kinds of studies:

- Authorised modifications to the imposed train timetables
- Limits of technical constraint infringement (location of bottlenecks in the network)
- Finding residual capacity by weighting each category of train
- Timetable accuracy
- Computing time
- Solving method: Exact or approximate.

Example: Line C of the Regional Express Network (RER)



## 11. LIPARI

([http://recherche.sncf.com/uk/projets/uk\\_lipari.html](http://recherche.sncf.com/uk/projets/uk_lipari.html))

### Objectives

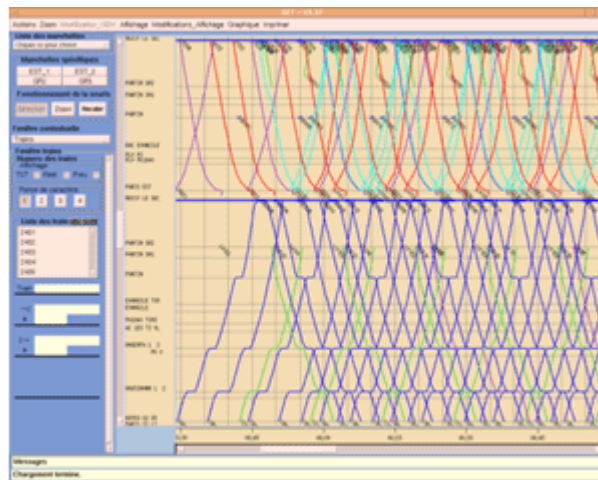
- To assess with simulations whether a control-command system defined as the reference model can manage extremely dense traffic and achieve a satisfactory level of punctuality.
- To define the target architecture of a new operational traffic management system based on the control-command system ERTMS 2 and semi-automatic traffic control and fluidification modules (advanced traffic control-command and supervision/management systems).
- To quantify with simulations the gains in punctuality obtained by the respective components of the target system and by the complete target system in comparison with the reference system.

The project has three main phases:

- Simulation of the reference system and assessment of its performance
- Research, design and development of the "traffic management" layer of the target system
- Simulation of the target system, assessment of its performance and identification of expected gains

The network infrastructures, the control-command system, the trains, the theoretical timetable and the control mode (manual or automatic) of the reference and target systems are modelled and simulated with **SISYFE**.

The "traffic management" layer of the reference and target systems is simulated using linear programming techniques and mathematical and heuristic optimisation algorithms. In the simulation, this layer dialogues with SISYFE in real time to receive current traffic data for the trains and to transmit instructions for train dispatching, routing and fluidification.



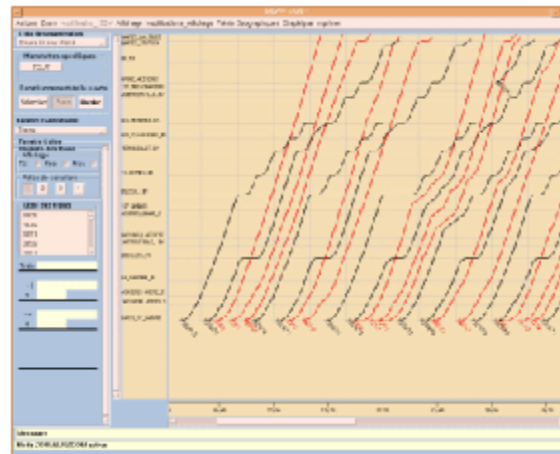


## 12. SISYFE

([http://recherche.sncf.com/uk/projets/uk\\_sisyfe.html](http://recherche.sncf.com/uk/projets/uk_sisyfe.html))

To acquire an effective means for conducting investigations and studies, SNCF has developed a software program called SISYFE (Simulateur du SYstème Ferroviaire – Rail System Simulator). It enables researchers to do precise simulations of the evolving situation on the rail network under normal conditions and when there are incidents affecting operations.

SISYFE runs on the principles of discrete-events simulation.



### 5 types of hypotheses can be tested and combined:

- Fixed installations (tracks and their profile, signal positions, switches, stations...) and the signalling system (BAL, TVM, ERTMS)
- Mobile elements (train) and operational personnel (performance of equipment, driving)
- Traffic management (train dispatching, route planning)
- Incidents (frequency, type, location, duration)
- Timetable structure

### Utilisation of SISYFE:

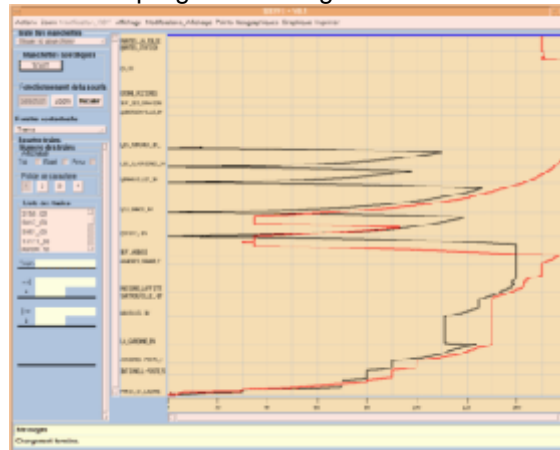
- Assessment of the robustness of traffic diagrams (i.e. their capacity to tolerate minor abnormal events during ordinary operations)
- Technical-economic studies for new control-command systems, modifications to fixed installations, etc.
- Definition of operational strategies
- Validation traffic supervision and operational management systems
- Training of dispatchers and controllers.

### Examples of studies done with SISYFE:

- EOLE interconnection: assessment of the robustness of the rail system with standard operations; demonstration of a new global traffic management system based on advanced control-command and supervision/management systems.
- Paris-Le Havre and Bettembourg-Basel freight lines: study of the contribution of an ERTMS2 control-command system compared with the present BAL system at several large rail nodes.
- Triangular interconnection of Coubert-bif. de Vémars: study of the robustness of the timetables at the Roissy hub in the context of increased interconnections and CDG Express operations.
- On-site training of controllers at the Château-Landon control centre – Paris-Est region (FISSA system).

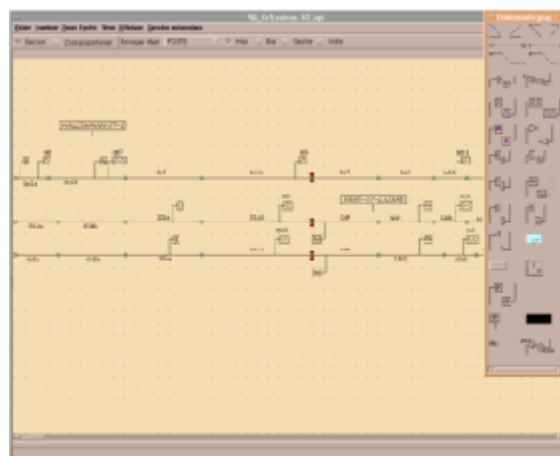
The simulation core of SISYFE reproduces the operation of the signalling system and the working of the mobile equipment.

While the simulation is being run, intermediate results are displayed graphically via space/speed, space/time and train progression diagrams on the network diagram.



Large masses of data are generated and stored during the simulation. When the simulation is finished, these data can be retrieved, analysed and summarised to supply statistical data for a report.

Upstream from the simulation module, a graphic editor is used to enter data describing the installations and the operational logic of the signalling.



### 13. RAILCAP

(<http://www.stratec.be/FichesEtudes/PlanGBrailcap.htm>)

The software package RAILCAP has been developed by STRATEC with a view to reinforce its capacity to analyse problems concerning railway capacity. The chosen approach is based on a static model that is well suited for studies on railway transport planning, railway network development and capacity allotments. These will find considerable usefulness in the possibility to make fast tests of the incidence of infrastructure and operation hypotheses. Indeed, Railcap measures in a straightforward way how much of the available capacity is used by a given operation program in each characteristic stretch of a given infrastructure. It thus brings to light all bottlenecks linked to the infrastructure and almost every bottleneck linked to demand. The effect of corrective measures can quite easily be tested. Time constraints are taken into account in terms of a precise given ordering of the trains during the test period. For this reason the model is not useful for the detection of minute conflicts in the timetables of the trains. These conflicts however are generally not considered at the planning and development level and can be tackled outside the model by a direct analysis of the operating schemes of the sections concerned.

RAILCAP requires detailed description of the tracks (down to block level), the position of switches, crosses, and signals (including their type) as well as the speed limits. The succession of trains is described by their routes across the network, the stops they make, and the length, maximum speed, and acceleration rate of each train. The method measures, through simulation, how much of the available capacity on different sections of the network (track sections situated on lines or in stations, network nodes or platform tracks) that is actually used, by computing, as a percentage, during how much of the available time the specified section is occupied by trains. The software produces reports on screen and on paper (tables and thematic charts of the network) indicating the capacity used by a scenario and the differences between two scenarios.

The great detail of analysis of bottlenecks enabled by RAILCAP has one major disadvantage in the fact that the modelling requires a lot of effort. Stratec developed another model in 1999 that makes simulations less time-consuming to prepare. According to Stratec, results from the simplified model have been counterchecked with the more sophisticated Railcap model and proven to come very close to those obtained with the latter.

## 14. OPENTRACK

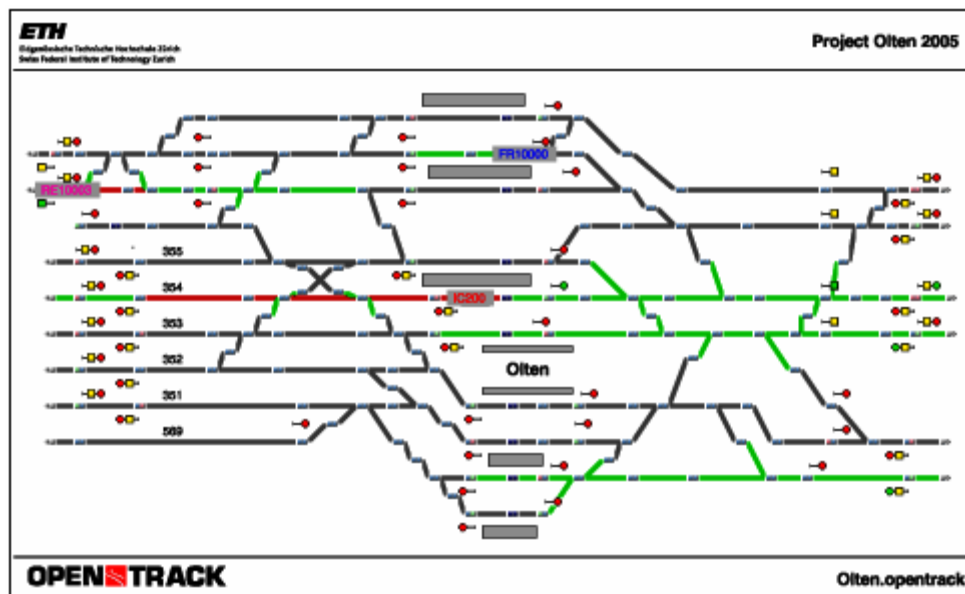
(<http://www.opentrack.ch/>)

OpenTrack - Simulation of Railway Networks - began in the mid-1990s as a research project at the Swiss Federal Institute of Technology. The aim of the project, Object-Oriented Modeling in Railways, was to develop a user-friendly tool to answer questions about railway operations by simulation.

OpenTrack supports the following kinds of tasks:

- Determining the requirements for a railway network's infrastructure
- Analyzing the capacity of lines and stations
- Rolling stock studies (for example, future requirements)
- Timetable construction; analyzing the robustness of timetables (single or multiple simulation runs, Monte-Carlo simulation)
- Analyzing various signaling systems, such as *discrete block systems*, *short blocks*, *LZB*, *ETCS Level 1*, *ETCS Level 2*, *ETCS Level 3* (moving block) or *ERTMS*
- Analyzing the effects of system failures (such as infrastructure or train failures) and delays
- Calculation of power and energy consumption of train services
- Simulation of Maglev systems (such as *Transrapid*)

OpenTrack describes a railway network in special graphs called double vertex graphs. A user can edit the network's topology graphically. Every element of the graph holds various attributes. An edge, for example, holds its length, the gradient, the maximum speed for different train categories and much more. A user can create and manage objects for edges and vertices, and also signals, switches, stations and routes. The following figure shows part of a topology.

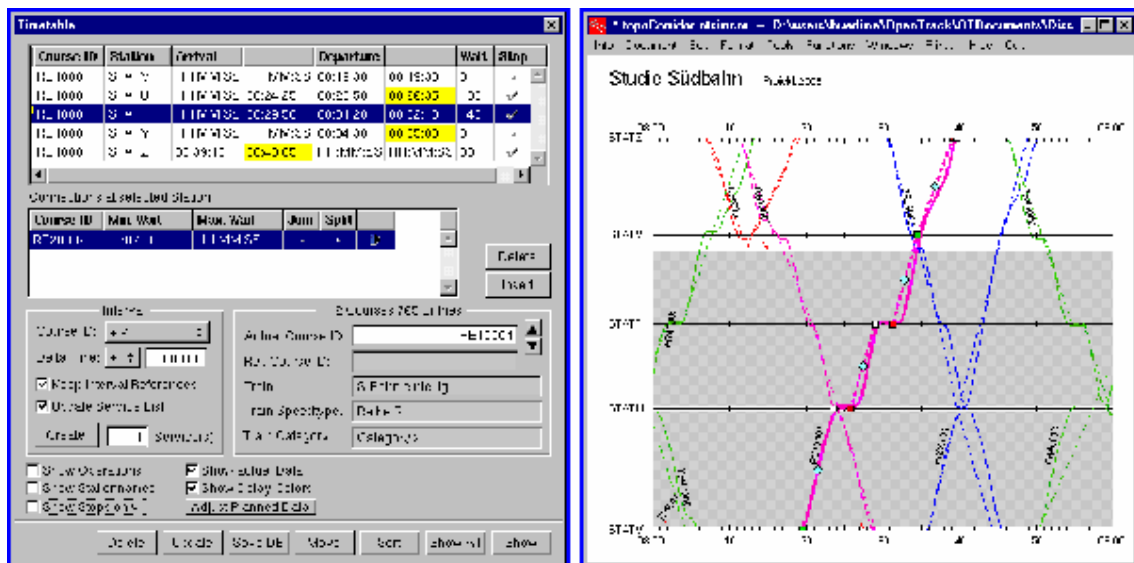


Example of a station

OpenTrack stores each locomotive's technical characteristics, including tractive effort/speed diagrams, load, length, adhesion factor, and power systems. A database organizes locomotives into groups called depots. A simulated train uses one or more locomotives from a depot together with a number of passenger or freight cars (carriages or wagons). Trainsets are also organized in a database.



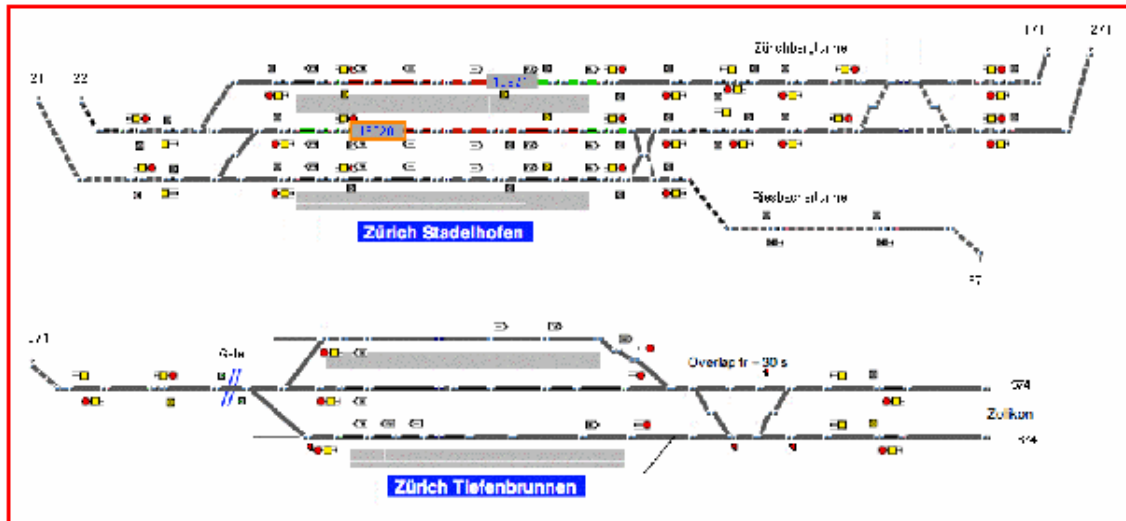
The timetable database stores information for each train at each station, including arrival and departure times, minimal stop time, and connections to other trains.



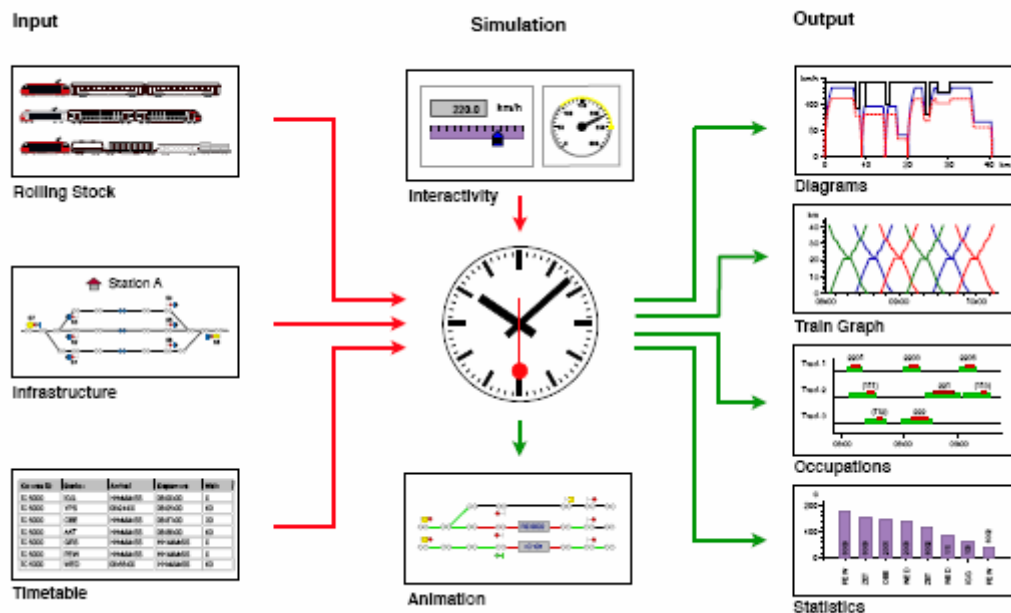
The user can edit the timetable data either in **textual form** (left window) or directly within the **train graph** by using the mouse (right window)

The following figure shows how the simulation tool works. Predefined trains run according to the timetable on a railway network. During the simulation, OpenTrack calculates train movements under the constraints of the signaling system and timetable. After a simulation run, OpenTrack can analyze and display the resulting data in the form of diagrams, train graphs, occupation diagrams and statistics.

OpenTrack handles single simulation runs as well as multiple simulation runs where random generators produce different initial delays and station delays.



Screenshot of OpenTrack during the simulation. The video can be [downloaded](#).



The modules of the simulation

During the simulation, trains try to obey the given timetable. The differential equations for speed and distance are the basis for calculating a train's movement. The signaling system of the railway network poses constraints. Occupied tracks and restrictive signal aspects may impede a train's progress.

During the simulation, every train continuously stores its speed, acceleration, position, power consumption and other data. This data can be evaluated after the simulation.

The user can watch the simulation in an *animation mode*, which shows the trains running and lets the user analyze occupied tracks, reserved tracks and signal aspects.

After a simulation, OpenTrack offers a number of evaluations. Evaluations of a train, line or station are possible. For a train, OpenTrack offers diagrams such as acceleration vs. distance, speed vs. distance, and obstructions. For a line, there are evaluations in the form of diagrams of train movements, route occupation and line profiles. Every station produces output about all the trains that used it, including arrival, stopping and departure times. The user can view output data in a diagram, or export or evaluate it in a readable ASCII table.

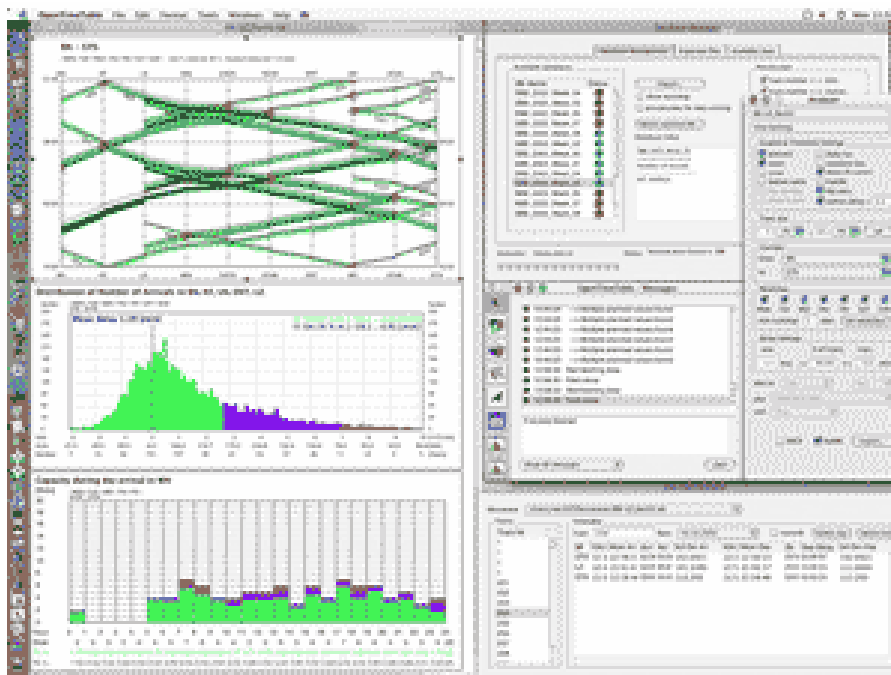
## 15. OPENTIMETABLE

([http://www.ivt.baug.ethz.ch/oev/opentimetable\\_e.html](http://www.ivt.baug.ethz.ch/oev/opentimetable_e.html))

A train that regularly operates behind schedule may cause delays to other trains and to rail operations as a whole. As a basis for better timetables, the computer program OpenTimeTable helps analyze how trains deviated from the timetable in the recent past. OpenTimeTable enables users to analyze systematic delays and fine-tune timetables, create more attractive services and better utilize infrastructure.

In the future, OpenTimeTable will offer features that automatically analyze train operations over time and notify users of any trend towards poorer service.

OpenTimeTable was developed as a research project at the [Institute of Transportation Planning and Systems \(IVT\)](#) of the [Swiss Federal Institute of Technology Zurich \(ETH\)](#) in cooperation with the [Swiss Federal Railways \(SBB\)](#).



This screenshot shows the Macintosh version of OpenTimeTable

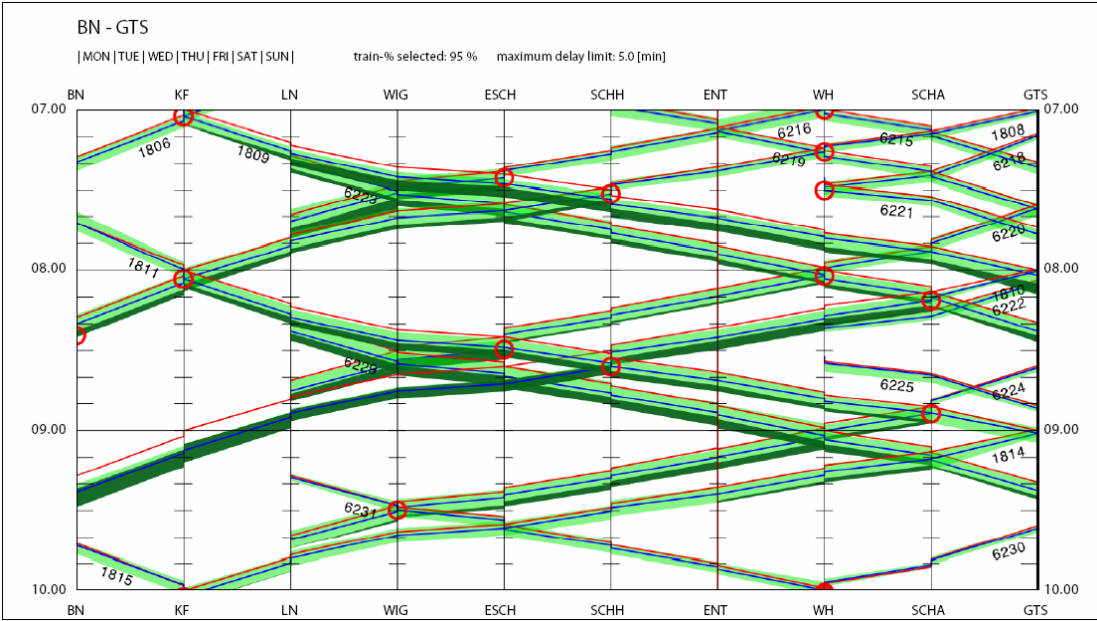
OpenTimeTables uses two main kinds of data:

- Scheduled train movements (as prescribed by the timetable).
- Actual train movements (as they really occurred on specific dates in the past)

OpenTimeTable brings together data on how trains should have run according to the timetable and how they have really run. On SBB, data on actual train runs comes from the SURF system, which continuously records train positions for SBB's dispatching centers. OpenTimeTable graphically juxtaposes "what should have happened" and "what really did happen". It thus helps the people responsible for timetables to analyze when and where delays tend to arise and to fine-tune the next version of the timetable accordingly.

This example shows the most important elements of the current version of OpenTimeTable:

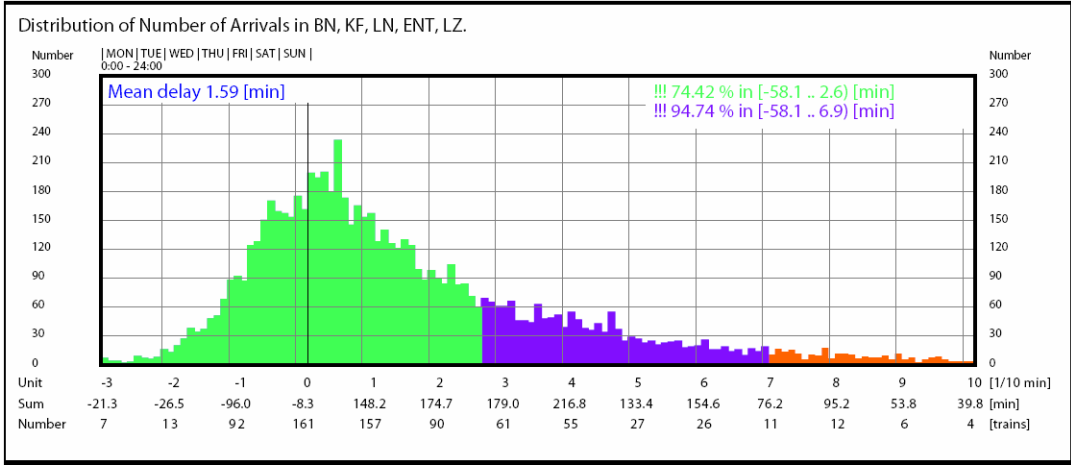




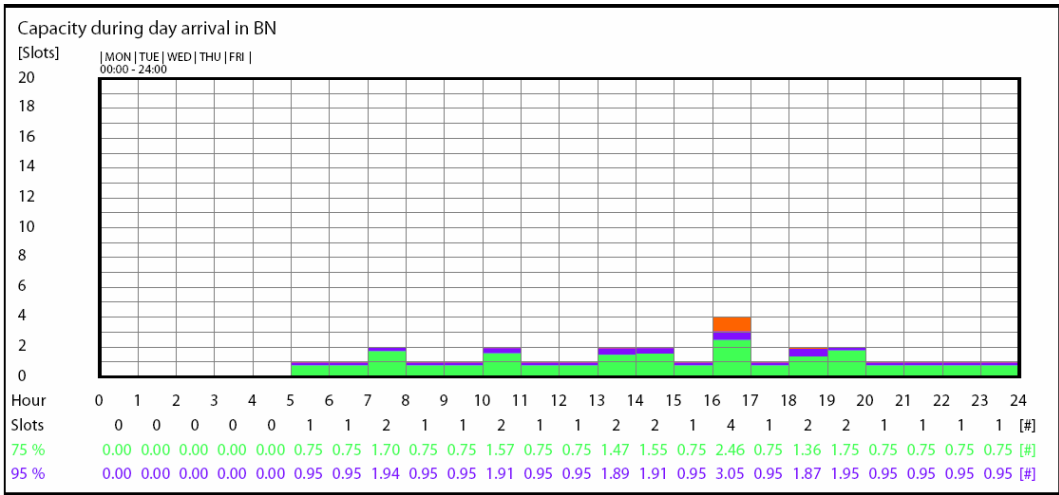
The figure on top shows the corridor between Bern and Luzern, Switzerland, which has many single-track sections. The red lines are scheduled train movements according to the timetable and the blue lines are mean actual train times for a chosen period.

The green areas show the space needed by the earliest 95% of the trains. Of this 95%, the dark green areas represent delays exceeding five minutes.

The two figures at the bottom show the distributions of arrival delays at Bern and Luzern.







OpenTimeTable allows the following kinds of user-guided analysis:

- Comparison between the timetable and actual train times (in graphical and text form).
- Mean train times; standard deviation of train times at a station (arrival and departure).
- Distribution of delays at stations.
- Delays for a given hour of day, weekday, week or month.
- Analysis of excessive dwell times at stations.
- Areas showing the space actually needed for trains. You can also see the space needed by the earliest n% of the trains and by trains whose delay exceeded a threshold.
- Analysis of time slots actually used.

## 16. VISION

([http://www.aeat.co.uk/rail/what/products/vision\\_fr.htm](http://www.aeat.co.uk/rail/what/products/vision_fr.htm))

VISION® simulates:

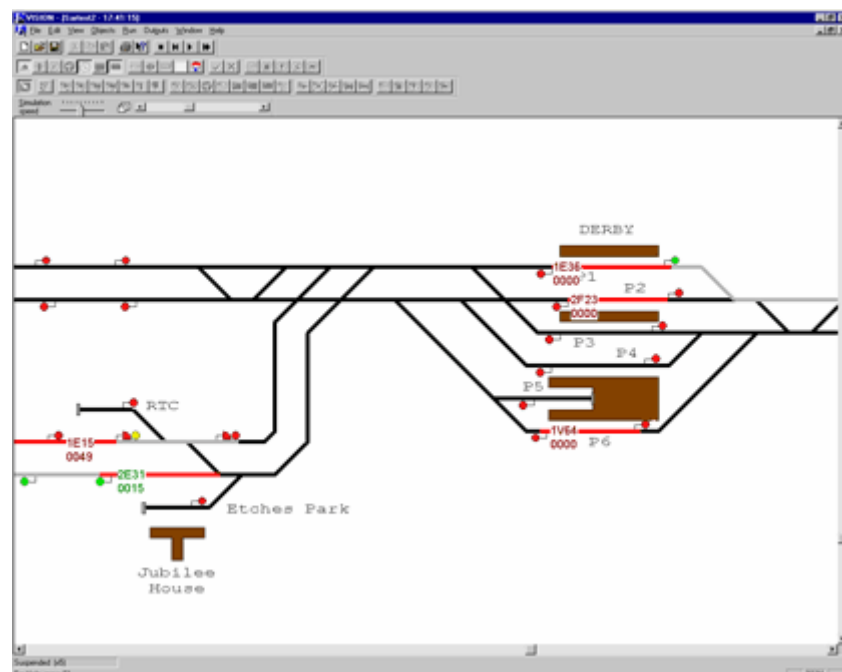
- Interaction of trains, the signalling system and the infrastructure on simple or complex networks
- Comprehensive and detailed “what if” situations applicable to railway operations in a given area
- Small or large areas (e.g. the whole of the WCML in one simulation)

Its advanced development also allows its to verify train headways and line capacity.

Simulation through VISION® is a swift and cost-effective means of:

- Demonstrating the feasibility of proposed projects
- Determining optimum operational solutions from multiple design options
- Ensuring operational requirements can be achieved

The display, a mimic diagram of the simulation area, shows time, track layout, signals, signal aspects, train positions, descriptions, driving mode and speeds, routes set, and estimated delays. The user is able to view and influence the progression of the simulation using the zooming and panning display controls provided. Several windows may display parts of the same simulation simultaneously.



VISION®'s capabilities are enhanced by specific features:

- Both planned and perturbed operation can be simulated
- Optional text window gives train reports at timing points and regulation reports on interaction between trains
- Libraries of rolling stock data and a range of signalling options
- All signalling and train regulation can be switched off, allowing trains to run independently of each other and of the signalling (effective as a model base run)
- Rapid creation (thanks to simple infrastructure input) and easy maintenance
- Conflicting movement detection - locking does not need to be input or checked separately

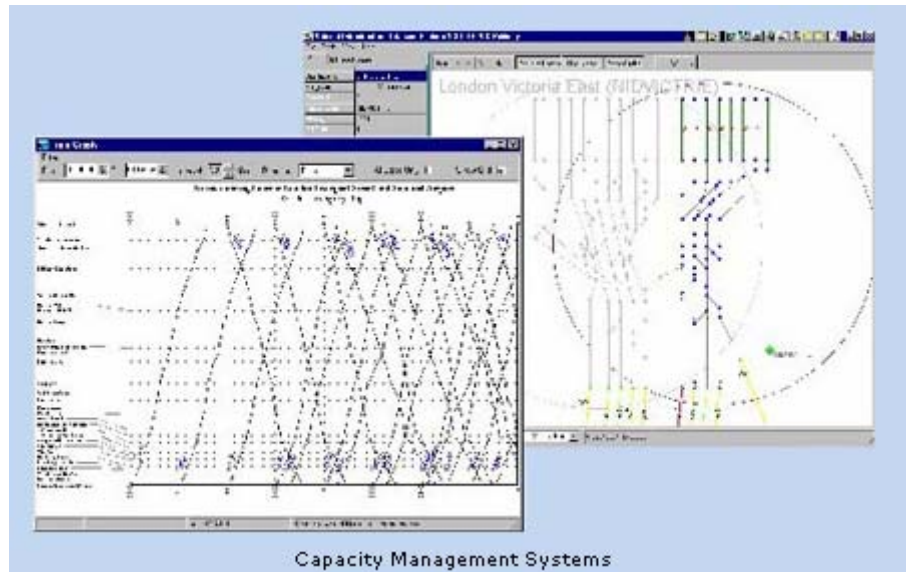
- High quality output graphs (e.g. time-distance, platform occupation and speed profile), reports and listings

## 17. CAPACITY MANAGEMENT SYSTEMS

([http://www.aeat.co.uk/rail/what/products/cms\\_fr.htm](http://www.aeat.co.uk/rail/what/products/cms_fr.htm))

Capacity Management Systems is a collection of computer-based models and analysis programs, and an integrated infrastructure database on which the software operates. Together, they provide a powerful system to plan the effective utilisation of the railway's capacity, both as it exists now and in the future.

This system is owned by Railtrack, for whom it has been developed. However AEA Technology's exploitation rights allow the use of the key elements of the systems, and the further development of the software for other clients.



### Benefits

- Easy 'what-if' scenario evaluation
- Rapid, automatic generation of timetables
- Simulation of operations to predict performance and identify remedies
- Identification of capacity available for sale
- Usage forecasts based on improved timetables
- Map-based presentation allows key issues to be quickly identified
- Powerful reporting capabilities allow detailed investigation and diagnosis
- Integrated toolkit means that data entry is reduced to a minimum
- National timetable and network database allows data sharing across the organisation

### The components of Capacity Management Systems:

- **Planning Timetable Generator** uses advanced optimisation technology to automatically generate timetables satisfying the commercial and operational constraints identified by planners. Using Planning Timetable Generator means:
  - Timetables can be assessed thoroughly and rapidly from a commercial and operational perspective, allowing a broad range of options to be considered
  - Fast, informed responses amongst all parties developing the planned level of service
  - Planners have enough time to consider strategic issues of service patterns and infrastructure investments, in addition to producing tomorrow's timetable

- **MERIT** is a strategic tool to test the implications of proposed timetables and/or infrastructure changes, or it identify where changes could be beneficial. It simulates railway operations over a large area, and it is calibrated using actual punctuality data to ensure that its predictions are valid. MERIT is fast, allowing several timetable or infrastructure options to be analysed quickly. The likelihood of equipment failure is calculated from observed data based upon the modelled infrastructure.
- **The Path Searching and Pricing (“PsaP”)** model assesses where on the rail network there is scope for running extra trains in the timetable. It does this by estimating the expected deterioration in train punctuality caused by running extra trains. It can also apply appropriate costing mechanisms
- Using **Geographical Information Systems** to display the results as maps, the Capacity Management Systems system can calculate a variety of measures relating to congestion and capacity within the rail network. It can analyse current operations or proposed new timetables over proposed new infrastructure. It provides a powerful visual presentation allowing bottlenecks and spare capacity to be quickly identified.
- The **SCORES** module compares a proposed new timetable with the present one, and measure the changes in those factors which make timetables more or less attractive to passengers. From these analyses, using passenger flow data and estimates of how the change in attractiveness influences passenger behaviour, the user can estimate the effect on usage of a new timetable.

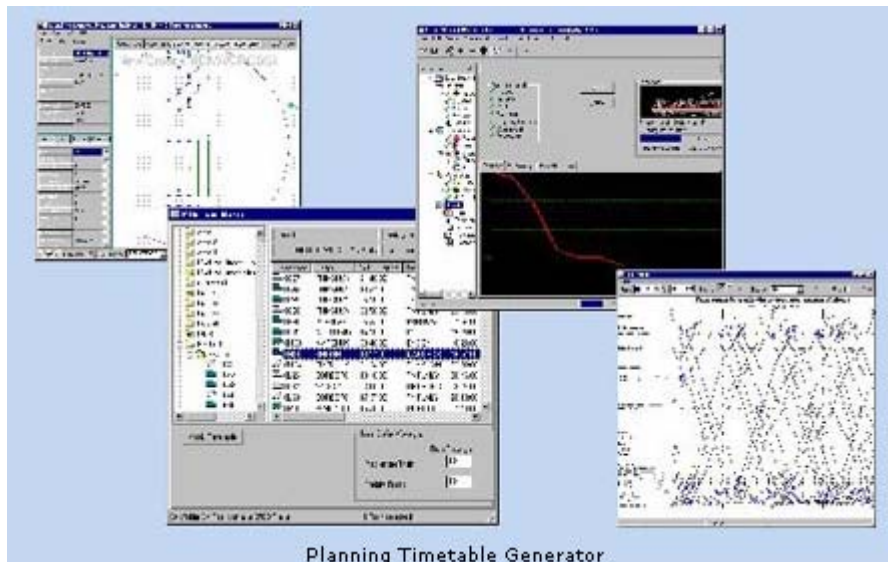
At the heart of Capacity Management Systems is an ORACLE database which holds details of the railway network. Approximately 30,000km of track and nearly 5000 junctions, stations, loops and crossovers are included. The database holds physical and operational information to enable the Capacity Management Systems tools to accurately reflect the layout and regulation of the network. A powerful visual editor is provided for creating new versions of the infrastructure. This allows the models to evaluate future and proposed scenarios prior to their implantation.

## 18. PLANNING TIMETABLE GENERATOR

([http://www.aeat.co.uk/rail/what/products/ptg\\_fr.htm](http://www.aeat.co.uk/rail/what/products/ptg_fr.htm))

Planning Timetable Generator automatically generates and assesses timetables rapidly, taking account of the requirements of infrastructure owners and service operators. This allows:

- assessment of the increased capacity, and hence the potential for additional revenue, resulting from network enhancements
- fast, informed responses amongst all parties developing the planned level of service



### Benefits

- Thorough and rapid assessment from a commercial and operational perspective, allowing a broad range of options to be considered in tactical and strategic planning
- Enables the capture and analysis of commercial and operational requirements, so that important characteristics of the timetable can be identified and preserved
- Provides feedback on problems encountered in developing the timetable, allowing planners to assess and make changes to requirements throughout the development cycle
- Enables very rapid consideration of 'radical' timetable options
- Robustness and pricing analysis can be provided via links to simulation packages

### What is Planning Timetable Generator?

The Planning Timetable Generator is a Windows based software package developed by AEA Technology Rail. It is a client-server application using an Oracle Database allowing data to be shared throughout the organisation.

It has been used on a range of projects by Railtrack, the infrastructure owners and operators in the UK. These include studies to investigate:

- the effect on capacity of enhancements to the East Coast Main Line
- spare capacity on lines running between Central London and a major airport
- renegotiating access rights during line closures resulting in a loss of network capacity on the lines between London and Brighton

Planning Timetable Generator is part of suite of tools known collectively as Capacity Management Systems which enable the evaluation of timetables from planning and operational perspectives. Capacity Management Systems incorporates a powerful infrastructure and

timetable database, allowing combinations of different layouts and service levels to be modelled and assessed using Planning Timetable Generator.

#### **Timetable evaluation in Planning Timetable Generator**

Timetables are evaluated in Planning Timetable Generator against both operational and commercial constraints. Timetables can be developed and assessed over any period from 1 hour to 24 hours.

Network layouts and their operating rules (minimum separations between trains) are held within a National Infrastructure Database that can be amended using a visual editor to represent present and future scenarios.

A utility (the Planning Timetable Generator Train Maker) is provided to build up service level requirements using new or existing service specifications.

Additional commercial features can be set to ensure that operators' commercial objectives are evaluated (e.g. regular spacing of services, connections and guaranteed paths).

Planning Timetable Generator's network modelling includes the representation of station and junction layouts allowing it to assess conflicting moves across the network, not just on open running track.

## 19. TPS/STRAX

([http://www.hacon.de/tps\\_e/facts.shtml](http://www.hacon.de/tps_e/facts.shtml))

HaCon are a German company that specialise in software for the rail industry. Their products include TPS: The timetable planning system for rail-borne traffic.

### TPS Modules

- Infrastructure data maintenance
- Timetable construction with interactive train graphs and conflict detection
- Integrated high precision runtime calculation (approved by the German Ministry of Transport)
- Interactive Graphical Timetables, definable by the user
- Simulation for conflict resolution (multiple stochastic simulation for stability analysis (timetable quality))
- Reporting
- Administration application
- Language independent user interface (British English, German and Danish available at the time)
- Interface server, interfacing with external systems (optional)
- Data Warehouse (optional)

### Data Management and Access

- Multi-user environment (e.g. consistent modification of one train by two users at the same time)
- Relational data model, completely normalized (3NF) for minimum of data redundancy
- Highly scalable ORACLE® Database
- Parallel management of different timetable- and infrastructure data versions (Lifecycle-Model); comparison functions
- Periodic timetables with operating day templates, option of continuous timetable planning (e.g. fluent transitions of timetable periods)
- Exchange of data between different timetable- and infrastructure data versions
- Backup, archive and recovery

### Security

- Transaction protection
- Undo/redo features
- TPS specific login layer for user authorization
- User-specific access rights ("User Restrictions") for infrastructure data:
  - Infrastructure versions with specific status,
  - Regional assignments (via areas or railway lines respectively) Timetable:
  - Timetable versions with specific status,
  - TOCs,
  - Train types General:
  - TPS applications,
  - Interface operations

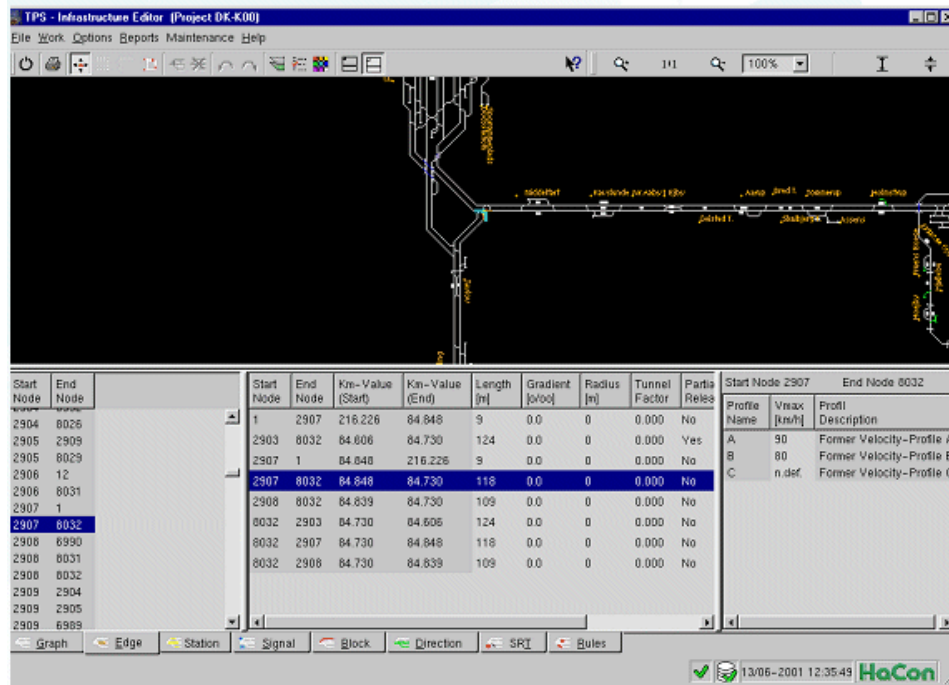
### Specific Model Properties

- Directed graph model for infrastructure representation
- Station and station track definition
- Support of all major signalling systems (including British 4-aspect signalling)
- Operating day templates and train assignment within the timetables
- Train related services (e.g. dining-car, sleeping-car, entrainment of bicycle etc.) and train assignment within the timetables

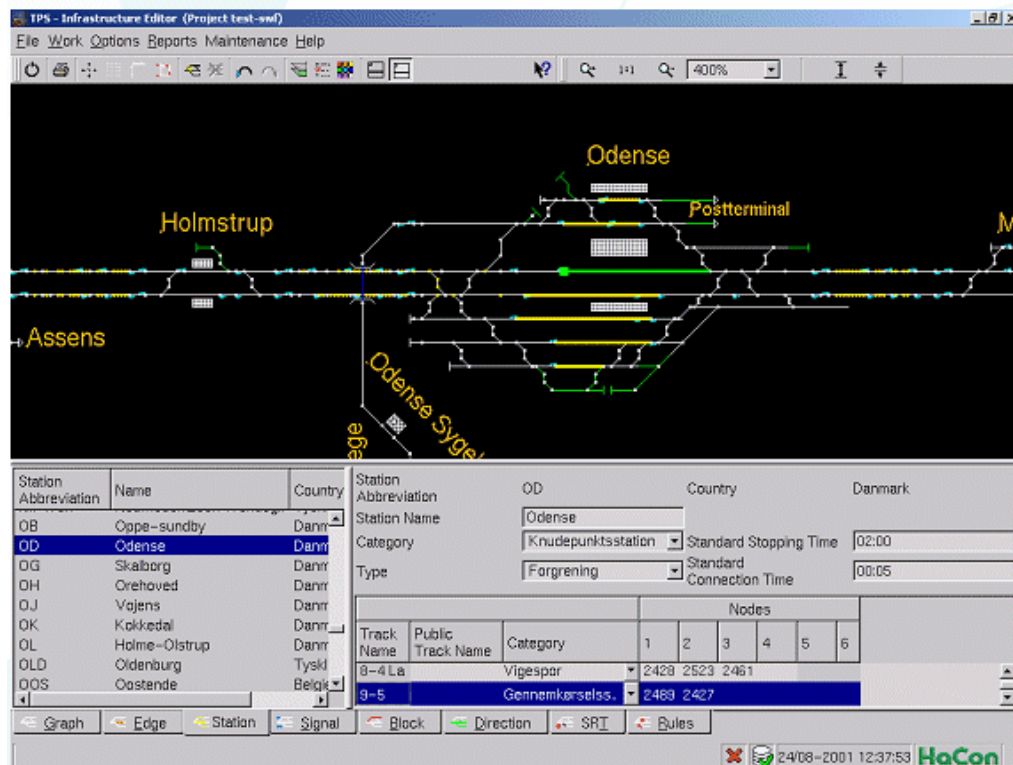


- Possessions supporting definition of validity period, day-time interval as well as information about type and extent of the obstruction
- TOC and contract information as key attributes linked to the trains

#### The TPS Infrastructure Editor section

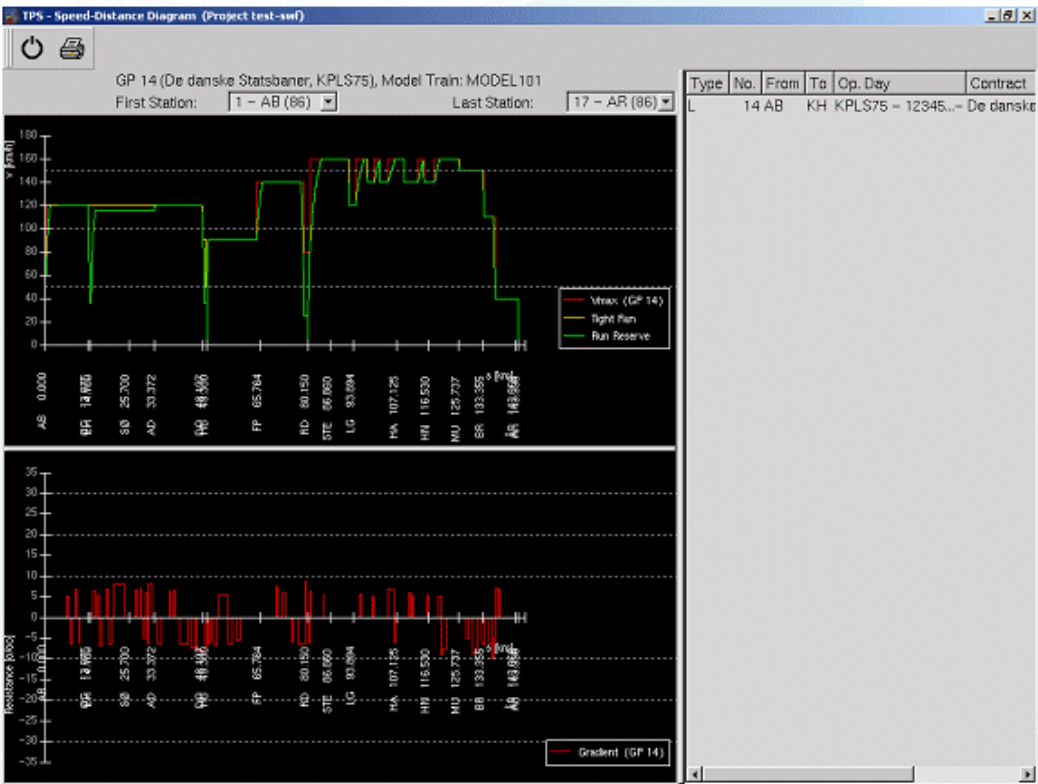


#### Editing stations and station tracks

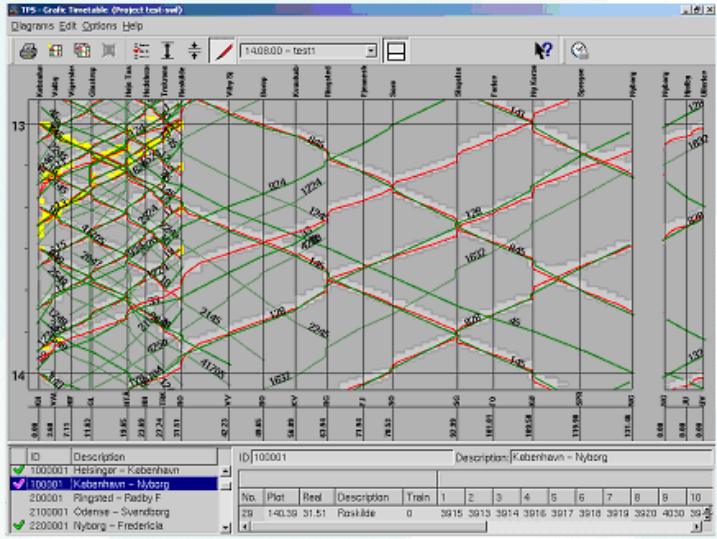




Runtime Calculation: Speed-Distance Diagram

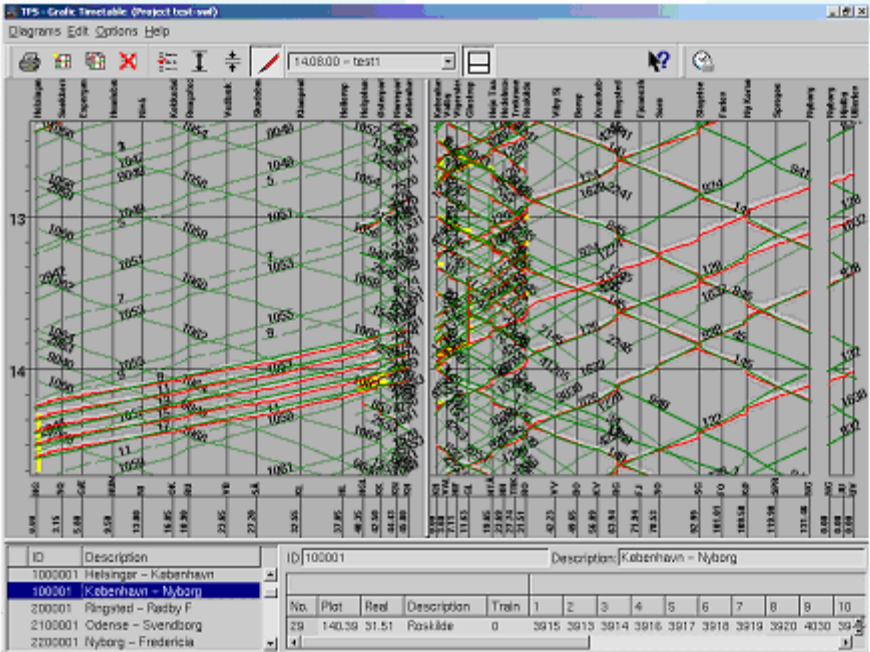


The TPS Interactive Graphical Timetable with occupation information and conflicts (yellow)

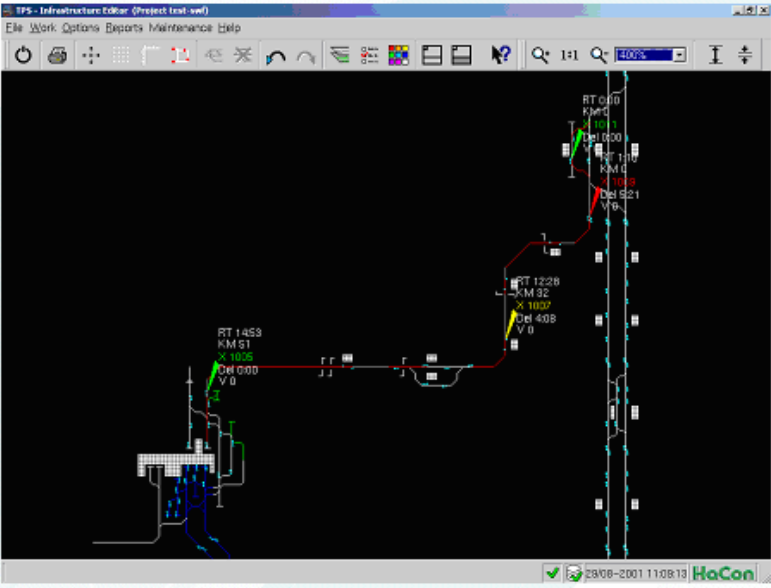




Concatenating arbitrary graphical timetables, forming a line sequence



Simulation within action: display of running trains with linked information including delay



## 20. MULTIMODAL

(<http://www.multimodalinc.com/>)

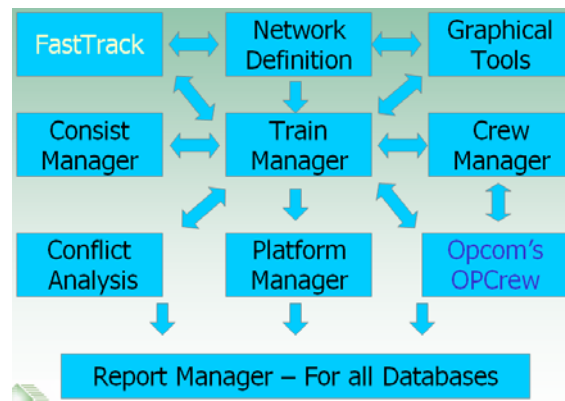
MultiModal produces two versions of the MultiRail system – MultiRail Freight Edition and MultiRail Passenger Edition. We also provide a MultiRail compatible capacity planning and optimization system called FastTrack II:

- **MultiRail® Passenger Edition** Fully integrated system for service planning including timetabling, track, equipment and crew management
- **MultiRail® Freight Edition** - Fully integrated system for freight service design and planning
- **FirstClass™** is an Algorithmic railway car classification system
- **FastTrack™ II** is an optimizer for capacity and meet/pass planning MULTIRAIL Passenger Edition (<http://www.multimodalinc.com/mrpe/MRPELongDescription.PDF>)

MultiRail is produced by MultiModal Applied Systems. The **Passenger Edition** includes most of the tools that are required by most passenger operators. MultiRail-PE is designed for all passenger railroads including inter-city, commuter, light rail and urban transit operations. MultiRail-PE is Windows-based and has integrated tools for train scheduling/timetabling, conflict identification, timetable publishing, time-distance diagramming, consist management, platform assignment, and crew management. MultiRail PE has an extremely flexible set of planning and operational tools including:

- Automated generation of train routes based on entry of selected key points
- Sophisticated timetable editor providing a single interface to manage the schedules, crew assignments, equipment assignments, publishing, dispatch conflict identification, and generation of time-distance diagrams.
- Timetable displays can be multi-corridor, and the routes displayed can be completely specified by the user on an ad hoc basis
- Time- distance analysis screens (includes graphical schedule manipulation) for "conflict analysis".
- Graphical Consist Manager with "drag and drop" train creation
- Train schedule output that is suitable for reproduction and public distribution (data, web or hard copy).
- Comprehensive crew management toolkit
- Import and export functions for schedule and network data
- Full set of reports including:
  - Train schedule summaries & statistics
  - Detailed train schedules
  - Station clock or line-up reports
  - Timetable reports
  - Crew bid sheets
  - Consist assignment/cycling & validation report

All of the MultiRail "Managers" are interrelated. Data that is updated in one Manager is reflected in the other Managers. There are about 50 pre-designed reports in the passenger edition. The FastTrack optimizer (yellow) is an additional system that is compatible with MultiRail. Opcom's OPCrew (blue) is another add-on system that optimizes crews and rosters and is compatible with MultiRail.



Any rail network map can be scanned into MultiRail to form the basis of the “link and node” railway network. The user simply clicks on the scanned image to place nodes and connects the nodes for links.

## Network Manager

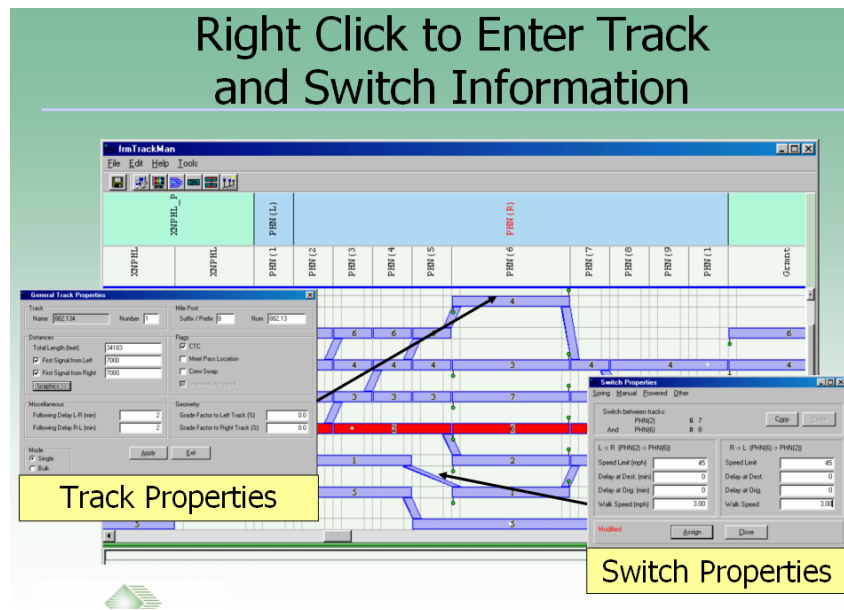
Graphical Tools for Building “Link and Node” Railway Network

The screenshot shows the 'Netzübersicht' application window. It features a menu bar (Datei, Bearbeiten, Möglichkeiten, Display, Werkzeug, Window, Hilfe), a toolbar, and several tabs (Betriebsstelle, Behandlungszeiten, Gleise, Verbindungen, Einzelheiten, Laufweg). A table titled 'Gleise' is visible, listing railway tracks with columns for Abb., Bezeichnung, Breite, Länge, Zeitzone, and Aufenthalt. A yellow callout box points to the table with the text 'Tables with Node And Link Details'.

Gleise	Abb.	Bezeichnung	Breite	Länge	Zeitzone	Aufhalt.	Abb.	Bezeichnung
EILENBURG	Eilenburg	51°26'33"	12°23'19"	GT1	00:00:00			
ASCHSELBN	Aschersleben	51°45'47"	11°16'12"	GT1	00:00:00			
DEBISFELDE	Debisfelde	52°28'11"	10°53'25"	GT1	00:00:00			
LÖWENBERG	Löwenberg	52°51'2"	13°3'3"	GT1	00:00:00			
JUTERBOG	Jüterbog	51°57'23"	12°50'53"	GT1	00:00:00			

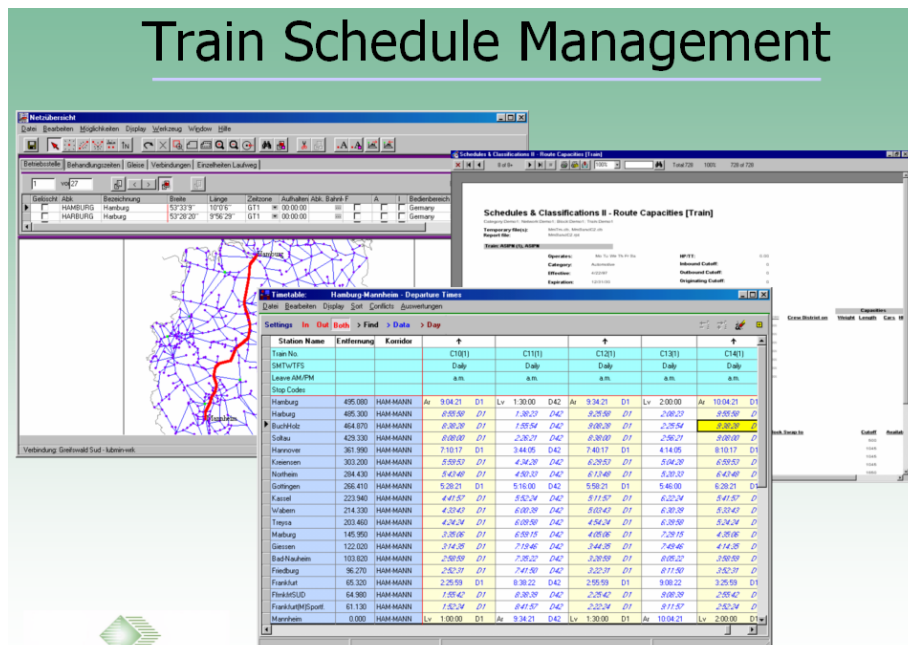
9

By “right clicking” on any track or switch, the user can define properties such as length, track dependencies, switch location/type and switch speeds. This information is later used to help identify train conflicts within a schedule. It is also used by the FastTrack meet/pass and capacity planning system.



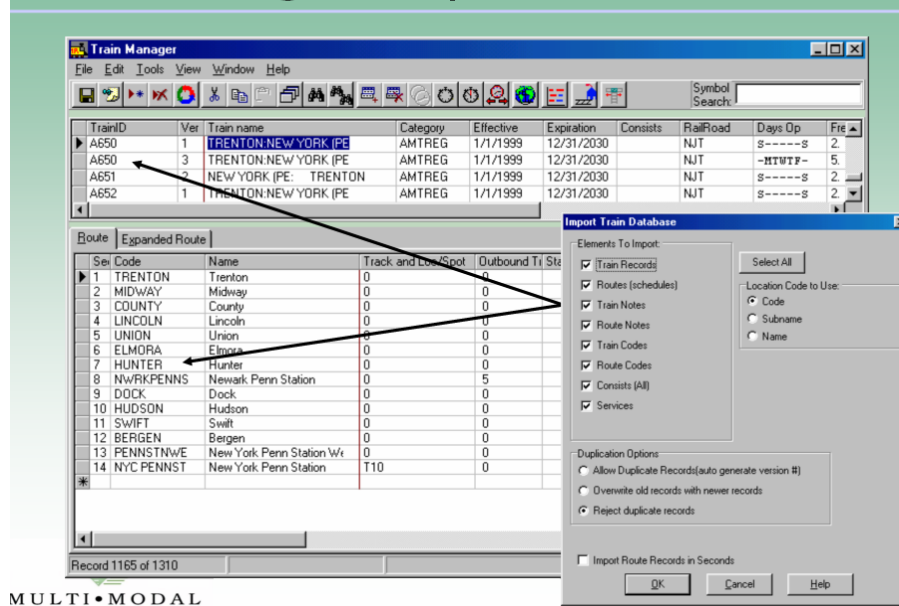
MultiRail-PE contains a significant number of features to support the process of train schedule design and planning. Included in MultiRail are two: Train Manager and Timetables - Train management environments.

The ability to generate timetables which display schedule information provides a powerful means to examine the feasibility and quality of a set of train schedules, the trains passing through a location, and the level of line congestion. MultiRail has the ability to generate timetables for any line segment or corridor for any period of time. You can also view multiple segments or corridors at the same time. Other powerful capabilities are the ability to edit, custom format, print and publish the times and schedules of trains across a set of corridors.



Within the Train Manager environment the user can specify individual trains, including both overall information and route specific information. The software is capable of assisting the user by suggesting train routings, intermediate time values, and making the process of adding points to a route as simple as clicking a mouse button. This is further augmented by the ability to look at train routings through maps, and time-distance diagrams. The main Train Manager main window is depicted below:

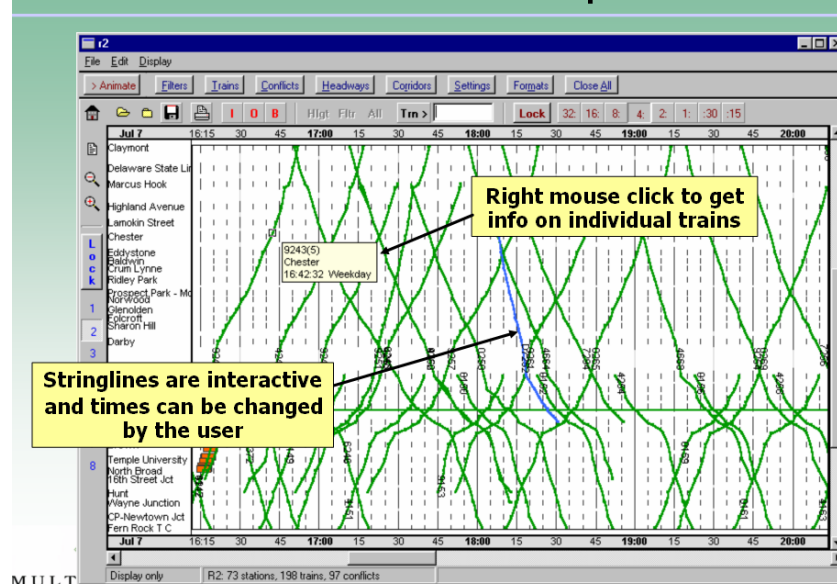
## Train Manager: Import or Build Trains



MULTI-MODAL

**VISTAS** is a MultiRail Manager for the interactive design and analysis of railroad train schedules, which is included in the basic MultiRail-PE license. It is based on a time-distance (time-space) diagram. MultiRail produces many types of string-line (time-distance) diagrams, which are built with user-defined rail corridors. The user can color the lines by track number, consist or train type. The lines on the graphic can be selected to set dwells or move train times. These changes can be saved to the train database.

## Time-Distance Graphics



Using the Timetable and Track Manager data, MultiRail has a full train simulation capability, which shows train conflicts in detailed graphical and tabular formats. The user can define the conflict rules within the track manager, when defining the various characteristics of the track arcs and switches.



## Timetable Used for Train Conflict Analysis

**A/D Times, Track/Platform, Run time, and Dwell Information**

**Line, Consist and Crew Information**

The results of the conflict ID simulation are highlighted on the Timetable screen. The severity of the conflicts are color coded and the non-conflict trains can be filtered out. By clicking on the conflict highlight, the user can see the details of the conflict.

## Conflicts Automatically Identified With Details

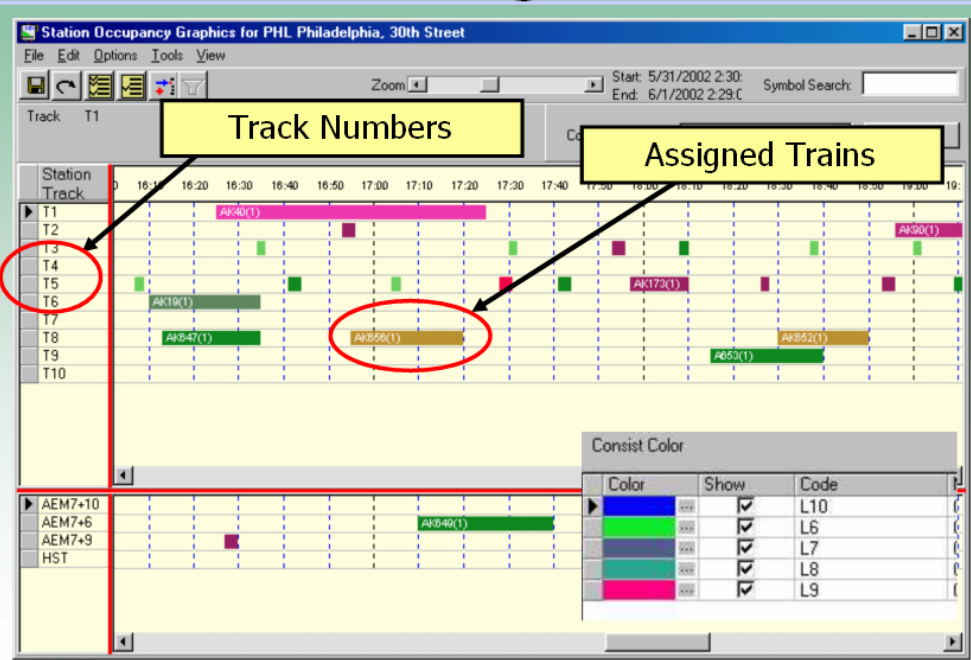
**Train A\_1026 and A\_1111 have conflict between 81st and 72nd**

**Conflicts details described, and filtered in timetable to aid problem resolution.**

The user can also use the track Manager to show the route of a train. Track manager shows the selected route or makes suggestions of feasible routes and non-feasible routes can be highlighted.



# Platform Planning Through Train-Base Track Assignments



## 21. FASTTRACK II

(<http://www.multimodalinc.com/prodserv.php?item=fasttrack>)

MultiModal has teamed up with Rail Sciences of Atlanta, Georgia to develop the next generation of railroad line capacity planning tools, **FastTrack™ II**. FastTrack™ II represents a major upgrade to our original FastTrack™ application and is a companion system to MultiModal's MultiRail®, the industry standard for rail service design and operations planning.

FastTrack™ II is a PC based train dispatching and meet-pass model capable of producing a feasible train dispatching plan for a user-selected corridor, given a set of proposed train schedules and a corridor's track configuration. FastTrack™ II uses Rail Sciences RDCAM® technology, a product based on 15 years of experience in developing real-time meet/pass planning systems and train dispatching software; the "nerve center" of **RDCAM** is a proprietary optimization algorithm which plans and executes train movements in accordance with management's objectives and schedule priorities. Applied as a standalone product, or in conjunction with MultiRail, FastTrack™ II can be used to:

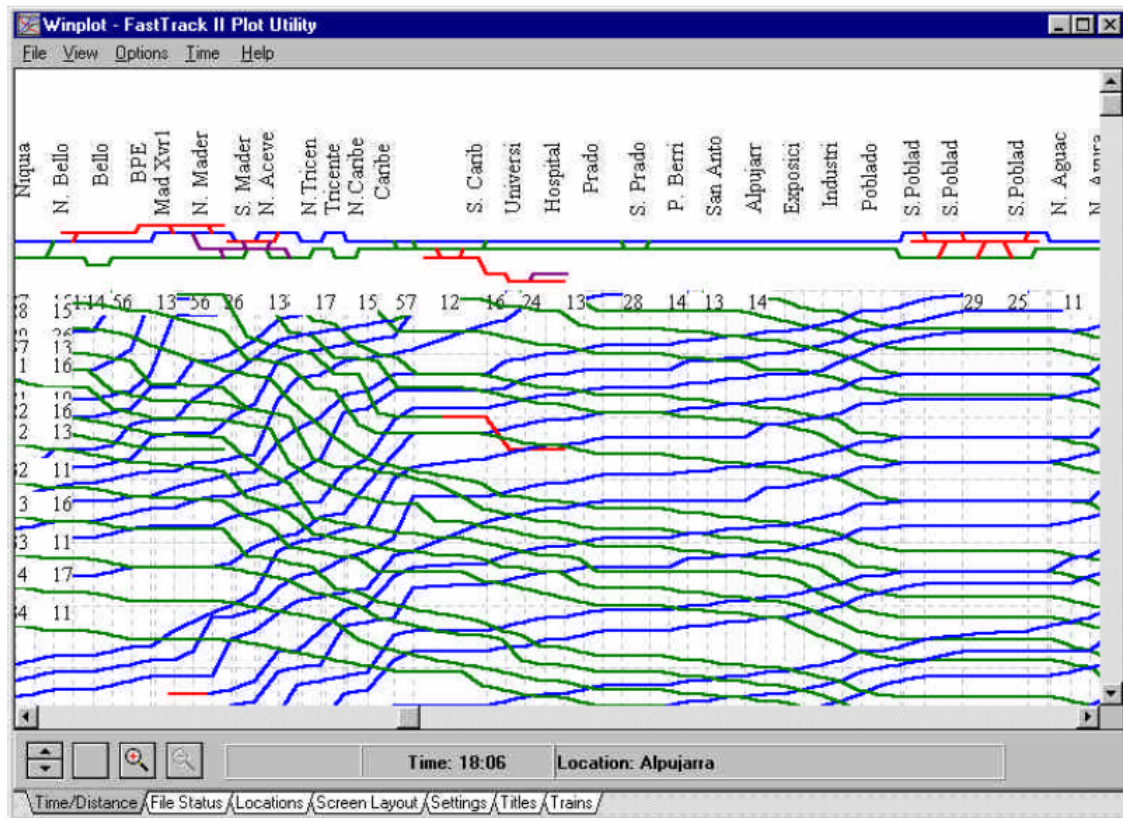
- Examine the feasibility of a set of proposed train schedules
- Test impact of proposed changes in operating policies on train service.
- Measure both theoretical and practical line capacity.
- Support line rationalization studies
- Plan siding placement and gauge the impact of siding extensions and removal.
- Measure the impact of proposed train service modifications that include:
  - Increased train volumes
  - Consist variations in locomotive power and car counts.
- Allow the user to measure impact of proposed changes to signal systems or other factors affecting train movement authorities.

FastTrack™ II is based on the field tested and proven technology from Rail Sciences. RDCAM® has been in use for over 15 years and has been utilized for capacity analysis modeling at many major railroads worldwide including Norfolk Southern, Conrail, Union Pacific and MRS Logistica (Brazil). FastTrack™ II is currently licensed by Norfolk Southern, Spoornet (South Africa), CVRD (Brazil) and ALL (Brazil).

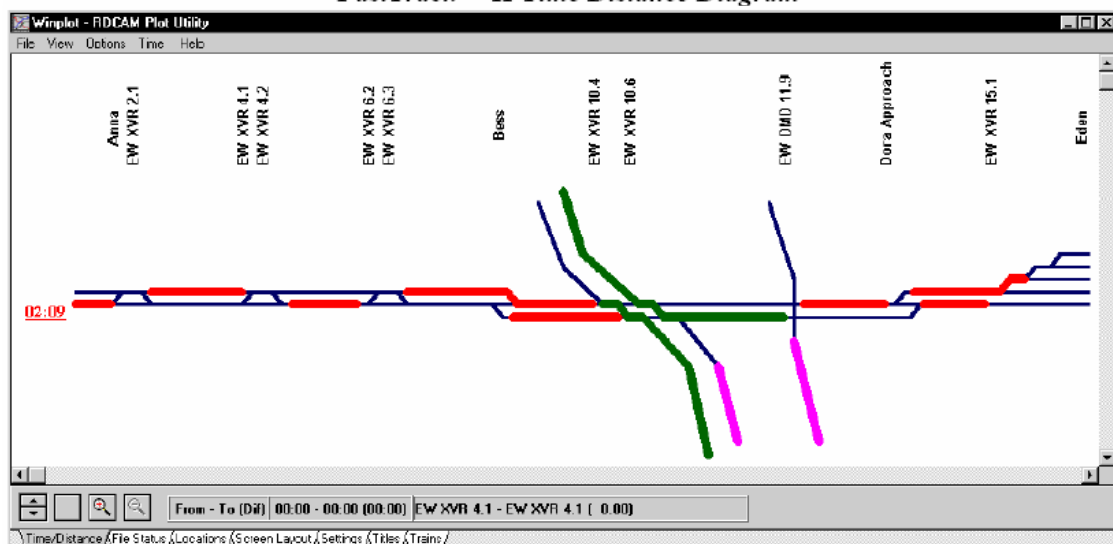
The most common applications for FastTrack™ II include schedule feasibility testing and line capacity analysis. By using FastTrack™ II to dispatch the "raw" schedules developed by service design, you can get an idea if the schedules are achievable if run at the designed times. FastTrack™ II can be used to test various scenarios and evaluate the impact of changes in the trains operated or the physical attributes of the line. Some of the key features of FastTrack™ II are:

- Operates over both single track and multiple track networks, with support for divergent routes.
- Handles over 20 days of scheduling
- Works with many existing Train Performance Calculators (TPC) including MultiModal's TTP™.
- Metric or English with multiple display options
- Considers both planned and unplanned track outages and delays due to such factors as M/W work, derailments, stalls, etc.
- Easy to use toolkit that allows construction of all train and track databases that are required for FastTrack™ II use.
- Extensive standard report capability.
- Flexible ASCII and standard database formats permit easy interchange of data with corporate databases and input of results to other systems, such as MultiRail™, for further analysis or report production.
- Wide variety of methods for restricting both routes and runtimes by both train class and train symbol.
- System considers all appropriate speed limit restrictions including limits by train class, milepost location, time of day, turnout, and individual train symbol.
- System can model wide variety of both signaled and nonsignaled territories with a near limitless combination of user-defined rail networks.

- Automatic generation of run times based on train class, consist, train position and acceleration/deceleration delays due to speed limit changes, enroute work and meet/pass delays.
- Another key function in FastTrack™ II is its animation, which allows both technical staff and line management the ability to quickly analyze what if scenarios. The animations can be used to show several days of train movements and complete graphical and table summaries are available for review.



*FastTrack™ II Time Distance Diagram*



*FastTrack™ II Animation Screen*

## CONCLUSIONS

In the next Table we summarize the names and main characteristics of the previous tools, where:

**Simulation:** The tool provides the function to emulate and graphically display real train operations in order to generate simulation models of railway networks where finer analysis of the timetable can be assessed.

**Timetable Optimization:** The tool provides optimization algorithms which schedules train movements and generate a timetable in accordance with a objective function, schedule priorities and network constraints.

**Timetable Manager:** The tool provides the function to edit train timetables date in graphic or tabulate way.

**Capacity Analysis:** The tool can be used to assess railway capacity.

**Infrastructure Manager:** The tool provides the function to model the existing infrastructure and to build up different infrastructure variants.

**Evaluation Manager:** The tool permits a graphical or tabular visualization of the results (timetables) and a more in-depth analysis of them.

**On Line:** The tool carries out studies of the railway network in real-time.

**Robustness Analysis:** The tool can help with the analysis of the stability of a timetable.

**Station Manager:** The tool assists the planners in solving the problem of routing trains through a railway station.

	Simulation	Timetable Optimization	Timetable Manager	Capacity Analysis	Infrastructure Manager	Evaluation Manager	On Line	Robustness Analysis	Station Manager
RAILSYS	✓	✗	✓	User-Deduct.	Very Detailed	✓	✗	User-Deduct.	✗
DONS	✓	✓	✗	User-Deduct.	✓	✓	✗	User-Deduct.	✓
PETER	✗	✗	✓	Very Limited	✓	✓	✓	✓	✗
ROMAN	✓	✗	✓	✗	✓	✓	✗	User-Deduct.	✗
VIRIATO	✗	✗	✓	Limited	✓	✓	✗	✗	✓
CAPRES	✗	✓	✗	✓	✓	✓	✗	✗	✓
FASTA	✓	✗	✓	✗	✓	✓	✗	User-Deduct.	✗
AFAIG	✗	✗	✗	✗	✓	✓	✗	✗	✓
DEMIURGE	✗	✓	✗	✓	✓	✓	✗	✗	✓
SISYFE	✓	✗	✓	✗	✓	✓	✗	User-Deduct.	✗
RAILCAP	✓	✗	✗	✓	Detailed	✓	✗	✗	✗
OPENTRACK	✓	✗	✓	User-Deduct.	✓	✓	✗	User-Deduct.	✗
OPENTIMETABLE	✗	✗	✓	✗	✗	✓	Future	User-Deduct.	✗
VISION	✓	✗	✓	User-Deduct.	✓	✓	✗	User-Deduct.	✗
CMS	✓	✓	✓	✓	✓	✓	✗	✓	✓
TPS	✓	✗	✓	✗	✓	✓	✗	User-Deduct.	✗
MULTIRAIL	✓	✓	✓	User-Deduct.	✓	✓	✗	User-Deduct.	✓
MOM-MALLAS	✗	✓	✓	✓	✓	✓	Limited	User-Deduct.	Limited



	Development	Use
<b>RAILSYS</b>	<b>RMCOM</b> (Rail Management Consultants GmbH) are a rail transport management and a software development enterprise	It is not certain that it is applied in operative environment.  It has been applied successfully in different projects such as the high speed lines Cologne-Rhein/Main and Sydney-Canberra, the city railways of Munich, Cologne, Sydney, Melbourne... or the rail network in Berlin and Copenhagen. <a href="http://www.rmcon.de/englisch/anwender.html">http://www.rmcon.de/englisch/anwender.html</a> y <a href="http://www.rmcon.de/englisch/referenzen.html">http://www.rmcon.de/englisch/referenzen.html</a>
<b>DONS</b>	<b>ProRail</b> , the inframanager of the Dutch railway network, executes the activities involved by the order of the Ministry of Transport, Public Works and Water Management.	Currently, ProRail (the inframanager of the Dutch railway network) and the Passengers division of Dutch Railways use DONS.
<b>PETER</b>	<b>Delft University of Technology</b> and <b>ORTEC</b> (Optimization & Decision Support Solutions)	ProRail (the inframanager of the Dutch railway network)
<b>ROMAN</b>	<b>Siemens AG Wien</b> , a leader in information technology	ROMAN is used in Germany and Austria
<b>VIRIATO</b>	<b>SMA and Partner</b>	VIRITATO is at least used in former Czechoslovakia, Denmark, the U.K., Portugal, France, Finland, Italy and Estonia. <a href="http://www.sma-partner.ch/vp/vreferenzen.php?bereich=viriato&amp;lang=e">http://www.sma-partner.ch/vp/vreferenzen.php?bereich=viriato&amp;lang=e</a>
<b>CAPRES</b>	CAPRES has been developed by the Laboratory of Intermodality, Transport and Planning ( <b>LITEP</b> ) of the Swiss Institute of Technology Lausanne ( <b>EPFL</b> ) in collaboration with the Swiss Federal Railways ( <b>SBB</b> )	It is used in Switzerland, France, Italy and the U.K
<b>FASTA</b>	FASTA has been developed by the Laboratory of Intermodality, Transport and Planning ( <b>LITEP</b> ) of the Swiss Institute of Technology Lausanne ( <b>EPFL</b> ) in collaboration with the Swiss Federal Railways ( <b>SBB</b> )	?
<b>AFAIG</b>	AFAIG has been developed by the Laboratory of Intermodality, Transport and Planning ( <b>LITEP</b> ) of the Swiss Institute of Technology Lausanne ( <b>EPFL</b> ) in collaboration with the Swiss Federal Railways ( <b>SBB</b> )	?
<b>DEMIURGE</b>	<b>SNCF Research</b>	It is currently used by SNCF Engineering
<b>SISYFE</b>	<b>SNCF Research</b>	It is currently used by SNCF Engineering
<b>RAILCAP</b>	<b>STRATEC</b> , group of specialist consultants from renowned	French and Belgian government



	consultancy companies and university research	
<b>OPENTRACK</b>	<b>Swiss Federal Institute of Technology</b>	Swiss Federal Railways, REFER E.P., Rhaetian Railways, German Railways, Ferrovie Nord Milano, Northern Ireland Railways,... <a href="http://www.ivt.baug.ethz.ch/oev/opentrack_e.html">http://www.ivt.baug.ethz.ch/oev/opentrack_e.html</a>
<b>OPENTIMETABLE</b>	OpenTimeTable was developed as a research project at the <a href="#">Institute of Transportation Planning and Systems (IVT)</a> of the <a href="#">Swiss Federal Institute of Technology Zurich (ETH)</a> in cooperation with the <a href="#">Swiss Federal Railways (SBB)</a>	<a href="#">Swiss Federal Railways (SBB)</a> and ProRail (the inframanager of the Dutch railway network)
<b>VISION</b>	<b>AEA Technology Rail</b> is one of Britain's leading technology companies. The company provides consultancy, technical services and products to three markets: Rail, Environment and Portable Power	?
<b>CMS</b>	<b>AEA Technology Rail</b> is one of Britain's leading technology companies. The company provides consultancy, technical services and products to three markets: Rail, Environment and Portable Power	?
<b>TPS</b>	<b>HACON</b> . Company established in Hannover, Germany. Its focus is: a committed team, efficient services and innovative products covering the sphere of traffic	German Railways, Austrian Federal Railways, Swiss Federal Railways, Netherlands Railways, Trenitalia, ... (Ver: <a href="http://www.hacon.de/hacon_e/ref.shtml">http://www.hacon.de/hacon_e/ref.shtml</a> )
<b>MULTIRAIL</b>	<b>MULTIMODAL</b> , Prize winning software and consulting services for railway planning and operations management	Canadian Pacific Railway, Indian Railways, Ferromex (Mexico), and others (Ver: <a href="http://www.multimodalinc.com/multimodal_clients.htm">http://www.multimodalinc.com/multimodal_clients.htm</a> .)
<b>MOM</b>	<b>Universidad Politécnica de Valencia</b> and <b>ADIF</b>	ADIF