Using the Computer Aided Rescheduling System *RegiDisp* for Cost Effective Optimization of Regional Traffic - State of the Art and Future Possibilities

Wilfried H. Koch

Ravensburg-Weingarten University of Applied Sciences, Institute of Applied Research, Department of Intelligent Systems, POB 1261, 88241 Weingarten (Württemberg), Germany

E-mail: koch@hs-weingarten.de

Abstract

In December 2002 the Hohenzollerische Landesbahn as the first railway company in Germany started to use *RegiDisp* as an innovative tool for optimization and quality assurance. In cases of delays this program follows a global optimization strategy and recalculates the timetable, suggests where the trains should meet (we have all single track lines) and informs well in advance if connections will be kept or lost. It also is extremely valuable when special trains have to be inserted into the existing timetable.

The program is well accepted by the staff using it and showed promising results during its first time of practical use.

Specially designed for use in regional traffic outside the big agglomerations the program only demands a limited amount of hardware resources for operation. Consequently object oriented implementation guarantees easy maintainability and fast response to future customers’ needs.

For the near future different extensions of the use are planned.

Motivation

Public transportation needs to increase its attractivity in order to compete with individual means of transportation. Fundamentals of this attractivity are among others:

- A high level of safety,
- reasonable fares and
- sufficient reliability.

From the customer's point of view, reliability mainly means a **guaranteed time of travel** with disregard to if transfers are necessary or not.

Delays extend the travel time not only of the train primarily affected, but also of connecting trains and - that is extremely important in our case - on single track lines they even affect trains running in the opposite direction than the originally delayed train. In cases of delays the traffic will operate on a corrected schedule which in most cases is far from being optimal and is only known to the dispatcher.

Even for network layouts that at the first glance seem simple, relocating the points of meeting and forecasting the best corrected timetable is similar to playing chess. This means that even in these „simple“ systems one should use a computer to do the job. In more complicated situations any non-computer-aided action will be far from the optimal solution. Only the use of a computer can guarantee the necessary quality, reproducibility and speed of the time-table correction.

Due to the author’s experience as a long distance commuter he has noticed the large need for rescheduling aids for all sorts of public transportation systems. His personal experiences have made him focus on a low cost solution for regional rail transportation.

Because in most cases regional public transportation is not the place for big investments, a **strict concentration on a low-cost solution** would hopefully ease the program’s introduction into practice.
Project

As the preliminary work on the topic had shown promising results, we were able to start a project together with a regional railway company in 2001. The goal of this project was to implement, test and evaluate the rescheduling aid at the Hohenzollerische Landesbahn AG in Southern Germany. This project was co-funded by the Federal Ministry of Education and Research and by the Ministry of Transport and Environment of the Federal State of Baden-Württemberg.

The network of our pilot project is shown in Fig. 1. The project area is limited by the stations at Herbertingen, Tuttlingen and Tübingen. The line management for the HzL owned lines occurs at Gammertingen, in the middle of the traffic area, whereas the dispatching decisions for the DB owned lines are made in Karlsruhe, more than 100 km away from the lines included in this project.

Some characteristic parameters of the project:

- total line length covered ca. 250 km,
- average frequency about 1.5 passenger trains per hour and direction, more in peak time.
- low frequency of goods trains superimposed.
- all single track,
- 4 nodes of the Baden-Württemberg fixed interval time table (3-Löwen-Takt, 3 lions tact) are included,
- two rail-to-rail transfer stations inside and three at the borders of the disposition area,
- ca. 30 stations with passing loops including the stations at the area borders,
- ca. 7 additional block stations,
- all DBAG lines and most HzL lines equipped with electric block.

The HzL have trains running on all lines covered by the project. They use the program for two purposes:

- To optimize the relocation of train meetings and ensure that transfers are met. Since there are also HzL trains running on the DB owned lines, the program is additionally intended to crosscheck the actions taken by the DBAG dispatchers and may be used to suggest alternatives.
- The HzL goods trains are often run on an ad hoc basis nearly. For these trains ReGiDisp is used for a quick and reliable design of conflict free timetables.

Fig. 1: Network of the pilot project
Solution

Data Model / Algorithms

The data model was developed pragmatically to serve the need of regional and branch railways. It allows for modeling all needed topological situations and all time-table data that we need on regional railways. For example we can define the track topology or important signaling conditions as well as actual and minimum running times. Keeping the data in a database guarantees a maximum of consistency and integrity of the data.

The time table data consist of three parts.

- The general time table as designed for a certain period (in most cases ca. 1 year). This time table contains all trains for all days and also the certain restrictions for the train traffic (e. g. operating on certain days of the week only).
- The daily time table. All trains operating at a certain day of the time table period are copied into the daily time table. It contains the nominal values of the trains’ operation.
- The disposition time table is basically the same as the daily time table, but during the day it is corrected due to the actual traffic situation. Also trains for special services are added and cancelled trains are removed.

Starting from a local optimization strategy we later implemented a globally optimizing algorithm. It is based on an A*-algorithm but uses sophisticated heuristics in the estimation process to reduce computational time. The algorithm tries to find the best conflict free corrected time-table. It not only optimizes inside of one line but also optimizes a network consisting of several lines.

The best corrected time-table is the one producing a minimum cost for the whole observed system. At the moment there are no standards for quality measurement. So, we defined a cost function which was easy to be implemented on the one hand and was plausible and acceptable on the other. Analogous to cost functions in control theory, we chose a weighted sum of delays at all stations. Lost connections are expressed in terms of time and added to the sum mentioned before. The weight factors are train and station specific. The basic formula for the cost is

\[ C = \sum_{i=1}^{m} (W_{Ti} \cdot (\sum_{j=1}^{n} W_{Sj} \cdot \Delta t_{ij})) + \sum_{k=1}^{o} W_{Ak} \]  

(1)

The parameters used in equation (1) have the following meaning:

- \( W_{Ti} \): Weight (importance) of connections / transfers
- \( W_{Sj} \): Weight (importance) of stations
- \( W_{Ti} \): Weight (importance) of train
- \( t_{ij} \): Delay of train i at station j

As there are no general measures for what an optimum time table is, the determination of the above parameters has to be done in close cooperation with the railway company using the rescheduling system.

Software Technology

The object-oriented architecture of the total program makes it easy to implement new cost functions and search algorithms so that new needs or ideas can be respected immediately.

The whole system has a clearly object-oriented architecture and was designed in several layers with strict separation between data keeping, processing and presentation. Due to these design principles, adaption to different needs such as

- using national standards and recommendations for time-table presentation,
- adding import filters for track, time-table or rolling stock data,
- implementation of dedicated cost functions or
• changing the inference mechanism.
generally will have local effects in the program code only.

Remarkable features of RegiDisp are:
• It is not a node, train, or line oriented, but it calculates a totally network oriented optimization of the total situation.
• Train importances (train classes) and priorities of connections can be assigned freely are naturally respected in the rescheduling calculation.
• The importance of a connection may be derived from the classes of trains and the expected or actual number of passengers involved.
• Unconditional transfer of personnel or rolling stock may be respected.
• Optimization possible for a theoretically unlimited number of primary delays in the system.
• RegiDisp produces deadlock-free solutions only.

Handling of RegiDisp
Before one starts to use RegiDisp, information about network, timetable and rolling stock has to be entered into the system's database.

To enter the data which are valid for a longer term is the task of some administrative staff. These data are:
• Input and maintenance of the master data (network topology, stations, types of rolling stock, train data)
• Input and maintenance of the timetable data
• Setting quality criteria
• Calibration of the system.

Short term data input has to be done by dispatchers or station masters.
• Modification of the timetable data in case of short-termed changes of the traffic (cancelled or added trains)
• Input of the actual traffic situation (delays)
• Start of disposition calculation
• Ranking of the suggestions calculated by the computer
• Acceptance of the disposition suggestion which seems to be the most favorable one.
• Handling the traffic (relocation of meetings, holding or giving up of connections) due to the accepted suggestions of the computer.

RegiDisp is user-friendly. Nearly all operational actions of the dispatcher/station-master can be done by use of the mouse.

Practical Experiences
From the beginning the program system achieved a high level of reliability. It contained all the functions needed for an average branch railway. During the first months of operation we added several features which were needed to fulfill special requirements of the HzL.

Generally we achieved a very high user satisfaction. A still remaining problem is the lack of communication between the network operators DBAG and HzL. Faster and more complete exchange of information would greatly improve the benefits of RegiDisp.

Some Results
Some interesting results for three classes of problems
• heavy delay of one train
• safeguarding of connections
• more than one primary delay
are shown below. In the first case (Fig. 2) the arrival of train 82052 in Balingen is heavily delayed (7.07 instead of 6.39). Delays in the system can be observed until 8.49.

Fig. 2: Rescheduling example 1. 82052 arrives 28 minutes late at Balingen.

In the second case (Fig. 3) 82008 leaves Albstadt-Ebingen at 12.45 (20 min late) but anyhow keeps its connection to RB27 at Hechingen DB. RB27 starts to Sigmaringen delayed but there it keeps its connection as well.

Fig. 3: 82008 is heavily delayed but connections to RB27 in Hechingen and from RB27 in Sigmaringen are met completely

In the last case we have two primary delays. 82008 leaves Albstadt-Ebingen at 12.35 (+10min) and 82011 leaves Tübingen at 12.43 (+10 min). Fig. 4 shows that the program can also handle multiple delays. Delays remain in the system until 14.36. Theoretically all the number of the conflicts that can be handled at one time is not limited.
Transfer of *RegiDisp* to other networks

*RegiDisp* was designed in cooperation with the HzL but it is a general system and not a special one for the HzL. It can be advantageously used on all sorts of regional railways. Also the use for mixed bus and rail service networks is possible. Besides the network of the project (Fig. 1) practical tests were done on the network of the Dürener Kreisbahn (Germany, region Cologne/Aachen) (Fig. 5).

Fig. 5: *Rail network for the test at DKB. Rescheduling was calculated for KBS 483 and 484. Influences from KBS 480 ab bus no. 10 were also taken into account during the rescheduling process.*
Integrating *RegiDisp* into the Railway Environment

At the moment our rescheduling system is implemented as a stand alone system for manual input and output. But we are sure that adding telematic elements will significantly cut development cost and also greatly increase the operational efficiency. As a result we expect a significant reduction of the total cost of ownership and a large increase in the user benefits.

The telematic elements can be added for different purposes:

- Train and traffic control.
- Passenger information.
- Software maintenance in various aspects.

The telematic system to be built around the rescheduling system as far as possible will use TCP/IP based services.

*Train and Traffic Control*

Presently the rescheduling system exists as a stand alone computer program being operated by one man at one place and the information transfer between the computer and the traffic system is handled manually. However all sorts of higher integration are possible.

In all these systems – stand-alone or integrated – the rescheduling application will not operate safely. Safety critical actions will be either delegated to interlocking systems or to human operators on its own.

*Off-line client/server system* with centralized database and local input of delays at the different manned stations. The result is calculated centrally and then redistributed to the stations for application to the transport process.

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![Diagram](image.png)

Fig. 6: The rescheduling aid *RegiDisp* in an off-line structure
On-line-open-loop-automation where the delays are entered automatically by axle counters or train number indicators, but the rescheduling results are manually transferred to platform indicators, signal boxes and trains.

Due to the modularization given by the object-oriented design it also should be easily possible to integrate components of the rescheduling aid into transport information and telematic systems of other suppliers.

**Passenger Information**

One other important application a computerized rescheduling system can serve, is to provide very early passenger information in cases of operational irregularities.

Currently the information given to passengers in these situations is often not very satisfying. The reasons are uncertainty about the traffic situation now and in the immediate future on one side and the additional workload the railway personnel has to shoulder due to the delays.

The passengers on the other hand demand the information

- as a basis for the adjustment of their travel plans (e.g. leave home later, take another route, change appointments at the destination).
- as a basis for short term action during travel (take a cup of coffee until the delayed train will arrive, proceed to changed track or bus position).
- simply to know what their further schedule will be like.
To improve the fulfillment of these demands, the information calculated by the rescheduling system (i.e., the forecasted actual schedule) can be used to control platform indicators and other information equipment on stations and bus stops. Additionally, this information can be used as an actualized input to general (nation- or statewide) or dedicated (e.g., one station only) traffic information systems in the internet, videotext, or similar media.

A special problem of the automated passenger information arises from an eventual instability of the traffic situation and its prediction. There is one iron rule that a published departure time in passenger traffic never may be after the actual departure time. This not only applies to the printed time tables but also for dynamically corrected time tables which are published by all types of electronic media.

If $d_s(T, L)$ is the originally published departure time of train $T$ from station $L$ and $d_a(T, L)$ is the actual departure time from there, and $d_{pi}(T, L, t_{pi})$ are the different dynamically published departure times published at the times $t_{pi}$, then the following conditions must be respected:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_s(T,L) \leq d_a(T,L)$</td>
<td>The actual departure time must be later or equal compared to the originally published departure time. (2)</td>
</tr>
<tr>
<td>$d_{pi}(T,L,t_{pi}) \leq d_a(T,L)$</td>
<td>The actual departure time must be later or equal compared to the one calculated by $\text{RegiDisp}$ and published at time $t_{pi}$. (3)</td>
</tr>
<tr>
<td>$(d_{pi}(T,L,t_{pi}) \leq d_{pi+1}(T,L,t_{pi+1})) &amp; (T_{pi} &lt; t_{pi+1})$</td>
<td>Departure times which are published as a result of a correction calculation for the time table must be constant or grow monotonously over the time. (4)</td>
</tr>
</tbody>
</table>

If these conditions are not satisfied, the passengers could be tempted to plan their journey or parts of it after the actual departure time.

In the moment we cannot guarantee that the time table correction process under all circumstances delivers monotonously ordered departure times. More probable is an oscillation of these values where some are before and some after the actual time of departure.

This means that a transmission of results calculated by $\text{RegiDisp}$ to components for passenger information may not be automated uncritically, but need some kind of authorization. The automation of this authorization will be part of our future work.

**Improved Input of the Actual Traffic Situation (Delays)**

In the actual state, the information basis for $\text{RegiDisp}$ are the arrival and departure delays at the block signals and the stations. In many cases, the input of these data is disadvantageous to the dispatcher’s workflow. Much more convenient is the input of the train’s actual position and a subsequent automatic determination of the delay by comparing the nominal and the actual time at a certain place.

In future solutions, the input will be taken from a GPS or similar device avoiding the need of human interaction. $\text{RegiDisp}$ is already prepared for the continuous input of position data.

In both cases, the input of a delayed train’s position will trigger the optimization process automatically.

**Telematics Assisted Software Maintenance**

Currently, our work in telematics is focused on software maintenance. This is because we expect an early return of investment during the pilot implementation.
The availability of telematic solutions for software maintenance should bring significant savings of travel time and cost and it should also shorten the answering cycles in our service and improvement activities. Software maintenance in our sense will mean a very broad range of activities. Planned actions concern:

- On-line delivery of new software versions and remote assistance for installation.
- Database management (revising the timetable, respecting changed infrastructure)

Occasional actions are necessary in cases of any unforeseen malfunction of the software caused by

- Programming errors,
- User/operational errors,
- Undue calibration or by
- Errors in the data base.

Telematics assisted software maintenance promises great help for development and remarkable customer benefits especially in cases improvable calibration.

Another Type of Successful Application: Dimensioning of Rail Infrastructure

In Germany – but not only here – it is commonplace that network operators try to reduce infrastructure in order to save cost. Very common is the removal of passing loops or second line tracks. These reductions of infrastructure normally respect the need of scheduled traffic only. They usually neglect the needs in cases of delays.

To determine the effect of the removal of infrastructure on scheduled traffic generally is very easy, but on

![Diagram](image)

Fig. 9: Rescheduling result for the München-Pasing – Mittenwald line. Reduced track infrastructure. Schedule similar to summer 1999 timetable. 5406 leaves Garmisch-Partenkirchen 15 min behind schedule. Crossings removed from Oberau to Eschenlohe (5406 x 5407) and from Tutzing to Wilzhofen (5406 x 5409). Further delay added for 5406. Other trains affected: 5407 max + 13.
the other side it is relatively difficult to forecast what will happen in the case of delay.

We can use **RegiDisp** with one database for the timetable and different databases for infrastructure (before / after modification of infrastructure) and assume some delays. Comparing the results one can easily judge how the absence or presence of infrastructure will influence the stability of operation.

**Investigation of Werdenfels Line in Upper Bavaria, Germany**

In 1999 DB Netz (German Rail Infrastructure) intended significant reductions of infrastructure between Murnau and Mittenwald on the Werdenfels line in Upper Bavaria. Three passing loops and one double track section which were not used for scheduled traffic were planned to be removed. These plans however did not take into account the effect of these removals on delayed trains.

The author was asked for an expert opinion about the effect of these infrastructural reductions on the stability of the timetable. The result was that those passing loops etc. which were not used in scheduled traffic brought great advantages in cases of delay. Finally - after long negotiations - the original infrastructure was left in place.

![Fig. 10: Rescheduling result for the München-Pasing – Mittenwald line. Present track infrastructure combined with improved signalling. Schedule similar to summer 1999 timetable. 5406 leaves Garmisch-Partenkirchen 15 min behind schedule. Crossings removed from Oberau to Ohlstadt (5406 x 5407) and from Polling to Huglfing (118 x 5409). No further delay added for 5406. Other trains affected: 5409 max + 8 min, 118 max. +3 min. Forecast of traffic situation about 1: 30h in advance.](image-url)
More Future Work

Increasing the Network Size

In the moment an excellently equipped PC (3GHz, 4 GB) is capable of handling a network size of 700 to 1000 km with a reasonable response time.

To handle a bigger network size and/or reduce the response time we have different possibilities:

- Tuning the existing algorithms by improving the heuristics and adding some features for handling of distant (in terms of time) narrow conflicts.
- Using more memory effective data representations and algorithms (e.g. SMA*).
- Creating a network of cooperating computers. Where each computer handles a certain district and the information about the time table correction is exchanged over a standardized interface.

Signalling and Point Setting

RegiDisp also could be used to control points acting like a [non-safe] operator of an interlocking system. Modern signaling more and more uses the automatic setting of points and signals without operator interaction. In this case we have to solve the conflict between early switching eventually causing delays to other trains or unnecessarily stopping cars at level crossings and late switching eventually causing delays to the train itself.

Time of switching in this case is derived from RegiDisp's actual time table, subtracting a certain time from the respective times of arrival and departure.

Fig. 11: Rescheduling result for the München-Pasing – Mittenwald line. Present infrastructure combined with improved signalling. Former crossing station Diemendorf reinstalled. Schedule similar to summer 1999 timetable. 5406 leaves Garmisch-Partenkirchen 15 min behind schedule. Meetings removed from Oberau to Ohlstadt (5406 meets 5407) and from Tutzing to Diemendorf. No further delay added for 5406. Other trains affected: 5409 max + 2min. Forecast of traffic situation about 1h in advance.
Use in other Places

Rail - Bus Connections

As mentioned, RegiDisp principally is applicable not only for rail but also for bus traffic. To get an better impression how it works in the context of rail-bus connections we make a detailed study for the rail and important bus lines in the Brenz valley (railway line Aalen - Ulm, Baden-Württemberg, Germany). As a result we will show, how bus and rail services can be connected on a high level of quality.

(German) Inland Waterways

A modification of our solution for other means of transportation is easily possible. There were some experiments for tramway and bus lines as well as for the German inland waterways.

A test application of our system to control the sequence of ships at the Wasserstraßenkreuz Spandau (waterways crossing Spandau) a bottle-neck in the German inland waterways showed, that its use is not restricted to rail respectively land transport.

Test of Fixed Interval Time Table in North East Poland

In cooperation with the Technical University of Gdańsk (Politechnika Gdańska), Poland RegiDisp was used to check the timetable stability and infrastructural needs for a proposed fixed interval timetable system.

Conclusion

The Rescheduling system RegiDisp as it has been developed at the Ravensburg-Weingarten University of Applied Sciences is a versatile and cost effective tool to improve the quality public of transportation.

- Experiences at the user’s site showed that we are on a correct and realistic path.
- In combination with telematic components there is a great potential for rationalizing operations and improving customer satisfaction as well.

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