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MAKING REGIONAL TRAFFIC MORE PUNCTUAL – A PILOT PROJECT OF COMPUTER AIDED RESCHEDULING ON A SOUTH GERMAN REGIONAL RAILWAY

Optimal rescheduling in cases of delay is important for improving punctuality and service quality in public transportation systems. Since it is impossible to solve the rescheduling task manually, computer aided systems are necessary for this purpose. In the past 10 years the Ravensburg-Weingarten University of Applied Science has conducted research activities in the field of computer aided rescheduling. The results have now reached the stage where the Hohenzollerische Landesbahn AG in Hechingen, Baden-Württemberg, Germany soon will be the first regional railway company in Germany to use computer aided rescheduling. This paper deals with the project as well as with the program system used. It shows some practical experiences and outlines possibilities for future use.

ZWIĘKSZENIE PUNKTUALNOŚCI RUCHU W REGIONIE – PILOTOWY PROJEKT NA POŁUDNIOWONIEMIECKICH KOLEJACH REGIONALNYCH

Optymalna zmiana rozkładu jazdy w momencie zaistnienia opóźnienia pociągu jest ważna dla poprawy punktualności i jakości usług publicznych systemów transportowych. Ponieważ niemożliwym jest rozwiązanie problemu zmiany rozkładu jazdy w sposób manualny, istnieje potrzeba wprowadzenia metod komputerowych. W ostatnim dziesięcioleciu Uniwersytet Nauk Stosowanych w Ravensburg-Weingarten przewodził poszukiwaniom rozwiązań w dziedzinie komputerowych metod zmian rozkładu jazdy. Osiągnięto wyniki na poziomie, na którym firma Hohenzollerische Landensbahn AG z Hechingen, Baden-Württemberg (Niemcy), będzie wkrótce pierwszymi regionalnymi kolejami w Niemczech, korzystającymi z komputerowego wspomagania w zmienianiu rozkładu jazdy. Referat przedstawia projekt, jak również zastosowany program. Ukazuje także zdobyte doświadczenie oraz możliwości zastosowań w przyszłości.

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1. MOTIVATION

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

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

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

The work described in this paper covers the reliability aspect of public transportation. 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. Delays prevent traffic from operating according to a published timetable. Instead the traffic will operate on a corrected schedule which in most cases is far from optimal and is only known to the dispatcher.

Even for systems and track layouts that at the first glance seem simple, relocating the points of crossing 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. **This is a true but often overseen fact!**

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.

Regional public transportation with its restricted infrastructure (often single track lines) has a large need for rescheduling tools and will profit greatly from their use. Such innovations are extremely necessary if regional public transport is intended to become a real alternative to individual traffic. But in most cases regional public transportation is not the place for big investments, so a strict concentration on a low-cost solution would hopefully ease the program's introduction into practice.

2. THE PROJECT

As the preliminary work on the topic showed promising results, we were able to start a project together with a regional railway company in 2001. The goal of this project is to implement, test and evaluate the rescheduling aid at the Hohenzollerische Landesbahn AG in Southern Germany. This project is 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.

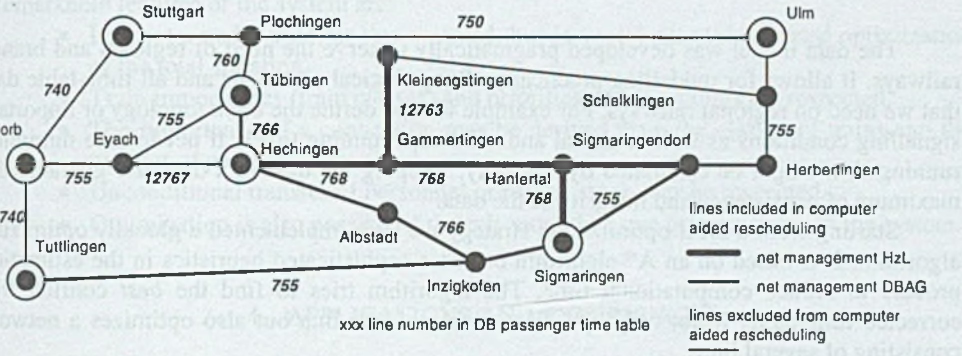

Fig.1. Map of the pilot area

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 way from the lines included in this project.

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The HzL have trains running on all lines covered by the project. They will use the program to optimize the relocation of train crossings and to ensuring that transfers are met. Since there are also HzL trains running on the DB owned lines, the program will additionally be used to crosscheck the actions taken by the DBAG dispatchers of the DB and might be used to suggest alternatives.

Some characteristic parameters of the project:

- total line length covered ca. 200 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,
- 7 additional block stations,
- all lines equipped with electric block.

3. THE SOLUTION

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

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

$$C = \sum_{i=1}^{m} (W_{T_i} \cdot (\sum_{j=1}^{n} W_{S_j} \cdot \Delta t_{ij})) + \sum_{k=1}^{o} W_{A_k}$$

W_A: Weight (importance) of connections / transfers.
WS: Weight (importance) of stations.
W_T: Weight (importance) of trains.
t_{ij}: Delay of train i at station j.

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

3.1. PROGRAMMING TECHNIQUE

The first versions of our Rescheduling Aid were hybrid software systems, using Delphi, the Interbase SQL Server and PDC Prolog. These implementation tools exactly reflected the main components of the system: Dialog and presentation, database and inference mechanism. Technically this was an ideal solution. But due to problems with human resources we gave up implementing in Prolog and started to use Delphi for the inference engine too.

The whole system has a clearly object-oriented architecture and was design 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,
- implemention of dedicated cost functions or
- changing the inference mechanism

- generally will have local effects only.

Remarkable features of the system are:

- It is not a node, train, or line oriented, but is a total network oriented optimization of the total situation.
- Train importances (train classes) and priorities of connections are respected.
- The importance of a connection may be derived from the classes of trains and the number of passengers involved.
- Unconditional transfer of personnel or rolling stock may be respected.
- Optimization is also possible if there is more than one primary delay in the system.

4. APPLICATIONS AND EXPERIENCES

Our program actually proved to be useful in two different types of applications. The original one which is the rescheduling aid and a derived one which deals with the dimensioning of rail infrastructure for the case of delays.

4.1. APPLICATION FOR RESCHEDULING

4.1.1. FIRST FIELD TEST AT DÜRENER KREISBAHN (DKB)

For rescheduling we first hd a short test on the Dürener Kreisbahn (DKB) a small but extremely innovative railway company which operates 2 branch lines with a total of 45 km length, situated between Köln and Aachen.

During the test we had the following result: In cases where delays endangered connections they could be identified (which connection?) and quantified (how much delayed?) far in advance. So the necessary actions, suggested by the rescheduling aid, could be taken very early and very exactly. This means: connections were kept which would have been lost without the use of the rescheduling system. Very encouraging for us were

- the good results,
- the short reply time of the system and most important,
- the immediate and total acceptance of the computer aided solution by the dispatcher on duty.

4.1.2. THE ACTUAL PROJECT TOGETHER WITH THE HOHENZOLLERISCHE LANDESBAHN (HZL)

This result enabled us to establish a pilot project for a greater area. This project is implemented in cooperation with the Hohenzollerische Landesbahn A.G. (HzL) in Hechingen. Compared to the version we used for the first field test in Düren we had and partly still have to add work in the following fields:

- increasing the reliability,
- improving the user interface (we started with an user interface for the engineer but will finally have to deliver one for the dispatcher),
- improving the modelling of the reality and
- calibration of the program for use in a greater area.

4.1.3. PRESENT BALANCE AND INTERMEDIATE RESULTS

Since there is still some time before the deadline of the projects we started a permanent lab test in April of 2002. This is done at our project partner's site. In this test the actual situation in the network is entered into the computer and the results are carefully examined by an engineer responsible for time table construction and operations. The results are not yet fed back into the railway system. Since it was installed at the HzL, the system runs practically with only minor interrupts and delivers accepted results. Our goal is to have the system operating at the dispatcher's work place when timetable changes on Dec 15, 2002.

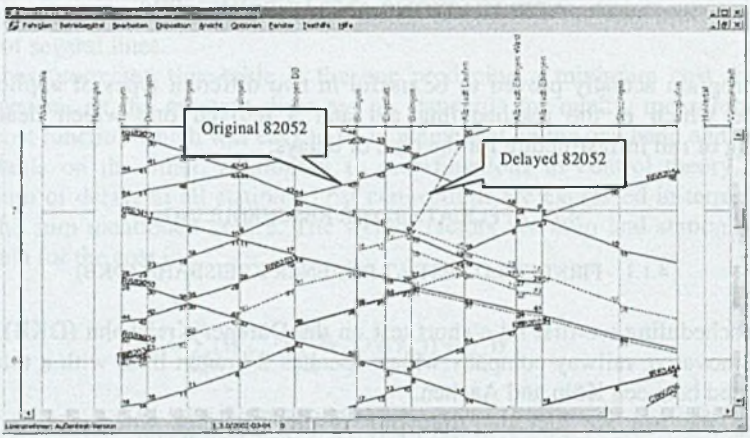

Fig.2. Rescheduling example 1. 82052 arrives 28 minutes late at Balingen

Some interesting results for three classes of problems 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. 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. 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.

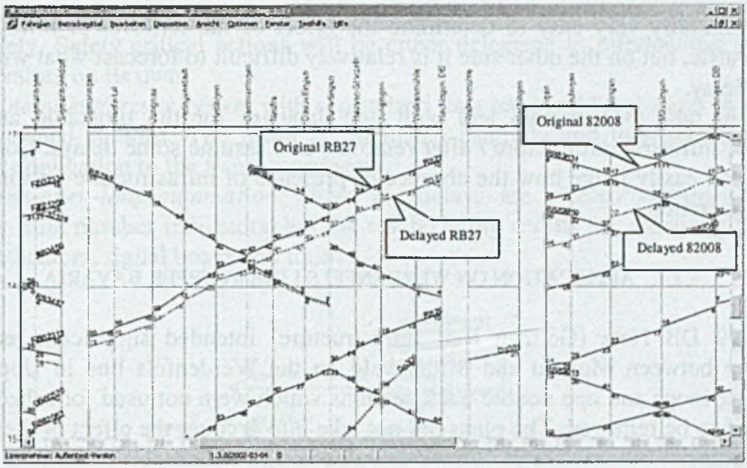

Fig.3. Rescheduling example 2. 82008 is heavily delayed but connections to RB27 in Hechingen and from RB27 in Sigmaringen are met

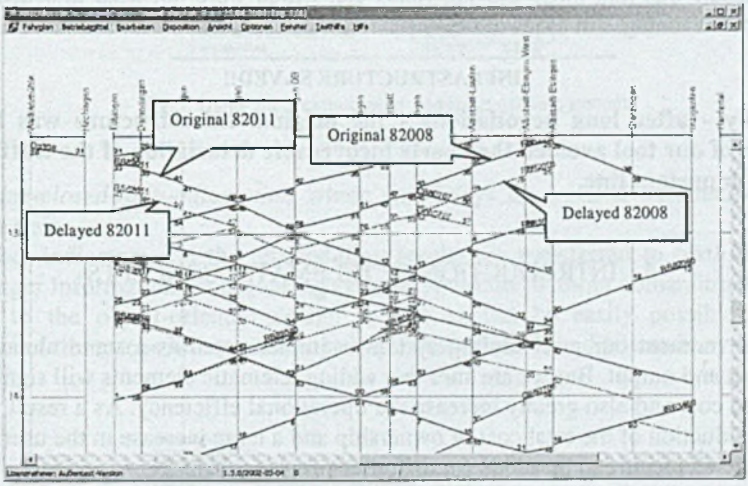

Fig.4. Rescheduling example 3. 82008 and 82011 are both delayed but transfer between one another is still possible in Hechingen

4.2. DIMENSIONING OF RAIL INFRASTRUCTURE

During early experiments with our program we got the idea that we can use our software not only to support railway operations but also for planning issues.

In Germany – and 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.

It is generally very easy to determine the effect of the removal of infrastructure on scheduled traffic, but on the other side it is relatively difficult to forecast what will happen in the case of delay.

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

4.2.1. APPLICATION ON WERDENFELS LINE IN UPPER BAVARIA

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 sections which were not used for scheduled traffic were planned to be removed. The plans 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. So different infrastructures were investigated in combination with different delays.

The result was that those passing loops etc. which were not used in scheduled traffic brought great advantages in cases of delay.

INFRASTRUCTURE SAVED!!

Finally - after long negotiations - the original infrastructure was kept. The application of our tool avoided the nearly incoverable detoriation of the traffic situation along that important line.

5. INTRODUCTION OF TELEMATIC CONCEPTS

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.

5.1. 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 data base 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.

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.

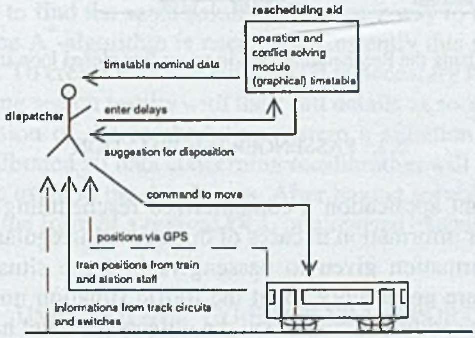

Fig.5. Using the Rescheduling Aid in an off-line system

On-line-closed-loop-automation where the delays are entered automatically by axle counters or train

number indicators and the rescheduling results are transferred to platform indicators (see Passenger Information), interlocking systems and trains without human interference.

Due to 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.

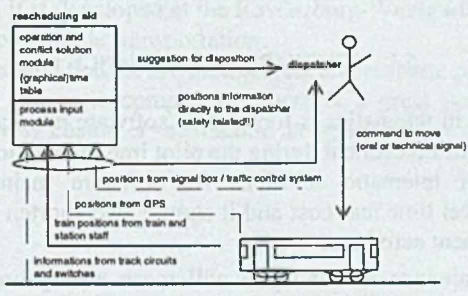

Fig.6. Using the Rescheduling Aid in an on-line open loop structure

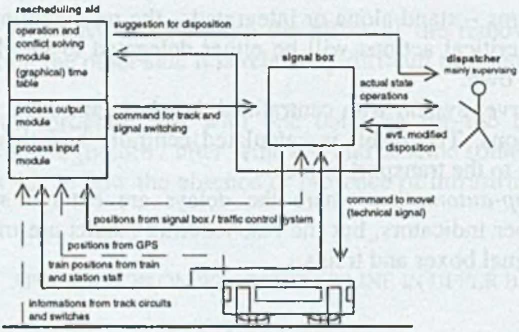

Fig.7. Using the Rescheduling Aid in an on-line closed loop structure

5.2. PASSENGER INFORMATION

One other important application a computerized rescheduling system can serve, is to provide (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 personel 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 coffe until the delayed train will arrive, proceed to changed track or bus position) or
- just for general reassurance.

To improve the fulfillment of these demands, the information calculated by the rescheduling system (i. e the forcasted 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.

5.3. SOFTWARE MAINTAINANCE

Currently our work in telematics is focused on software maintainance. This is because we expect an early return of investment during the pilot implementation.

The availability of telematic solutions for software maintainance should bring significant savings of travel time and cost and it should also shorten the answering cycles in our service and improvement activities.

- Software maintainance 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 managment (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.

Software maintainance by telematics promises great help for development and remarkable customer benefits especially in the case of calibration errors.

During our research we found some quantitative measures for improvable searches. I. e. after a solution for the rescheduling problem was found it often can be determined if there is a significantly faster way to find the same solution. If a faster way to find the solution exists, often a recalibration of the A^*-algorithm is necessary. Currently this must be done manually by the development team. To create versatile solutions it is necessary for the developers to get to know all the unsatisfying search results with their full details as soon as possible.

So if during operation of the rescheduling system a situation is detected where the algorithm should be recalibrated all data concerning recalibration will be automatically and at once transmitted from the users to the developers. After having solved the problem, they will send back the solution in the form of a revised DLL or a revised executable.

6. USE IN OTHER TYPES OF TRANSPORT

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

7. CONCLUSION

1. A rescheduling aid as it is developed at the Ravensburg-Weingarten is a versatile and cost effective tool to improve public transportation.
2. Lab and field trials showed that we are on a correct and realistic path.
3. In combination with telematic components there is a great potential for rationalizing operations and improving customer satisfaction as well.

8. ACKNOWLEDGEMENTS

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