Automatic conflict detection and decision support for optimal usage of railway infrastructure: results of pilot site operation

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Abstract

The Conflict Detection and Decision Support (CD/DS) system assists the train process supervisor in keeping the route-setting scheme up-to-date and free from conflicts. During 1999, the CD/DS system was approved and authorised for installation and pilot site operation in the western area of the Netherlands. For the first time, the system was used by supervisors. Train movement predictions, reporting and conflict resolution were evaluated under operational conditions. The system fulfilled expectations and largely satisfies the end user, i.e. the train process supervisor. This paper describes the CD/DS process and presents the results of the trials.

1 Introduction

Netherlands Railways are operating an increasing number of trains (about 6 000 per day) in order to provide the required transport capacity. This results in very intensive usage of the available infrastructure, and hence a reduced margin for readjustments. Relatively small disturbances can lead to major disruption if not handled appropriately. The route-setting process has been changed, in order to manage this number of trains effectively and to maintain the product quality required in terms of reliability and punctuality. The process has shifted from dispatching routes manually, based upon a timetable, towards automatic route setting, based upon an up-to-date route setting scheme.

Tasks of the train process supervisor

It is the train process supervisor's responsibility that train movements be performed safely under all circumstances. His main task is to maintain a short-term up-to-date route-setting scheme for passenger and freight trains and for shunting movements. He also monitors passenger connections, relationships between rolling stock and the order of trains departing to the open track.

The route-setting scheme is derived from the traffic plan, the relationships between rolling stock and the available infrastructure. For each train, the *route setting scheme* shows (for instance) the kind of route, the initial and final tracks and the time at which the route is to be set. The *traffic plan* defines train services and timetable information (e.g. arrival and departing times, passenger connections, whether the service is stop or run through, train type, type of rolling stock, etc.). Examples of *relationships between rolling stock* include joining two trains, splitting up a train and changing the train number.

Conflict types

End users (supervisors), specialists and designers have defined a list of conflict types. The readjustments that a train process supervisor can perform in the route-setting scheme are limited by the *regulations* of the Netherlands Railways and by the *dynamic* dependencies of the planned and actual train process.

This results in the following conflict types:

Regulation conflicts

An example: Exceptionally wide or heavy trains (such as trains carrying military equipment) are not allowed to run on all tracks of the infrastructure, and this restriction is laid down in regulations. Any violation of these regulations that occurs on the tracks and points inside the station area is detected and reported as a conflict.

Dynamic conflicts

These conflicts are caused by the dynamic dependencies in the execution of the route-setting scheme.

(Traffic)

1. Missed passenger connection due to late arrival of incoming train.
2. Train too long for platform.
3. Time difference between arrival and departure less than minimum required dwell time for passengers.
4. Train sequence differs from order in timetable.

(Rolling stock)

5. Missed rolling stock connection when coupling trains.
6. Order of arriving trains to be coupled differs from planned order.

(Process, i.e. use of infrastructure)

7. Conflicting routes using same infrastructure at same time.
8. Platform occupied when another train was scheduled for platform.
9. Route not available due to infrastructure out of service.
10. Unnecessary delay due to fixed order of trains.

2 CD/DS System

The on-line CD/DS system comprises three main entities: Prediction, Conflict Detection and Decision Support. Figure 1 depicts the system architecture, which is explained below. Refer to (Stolk [2], Makkinga, Metselaar [3]) for more details.

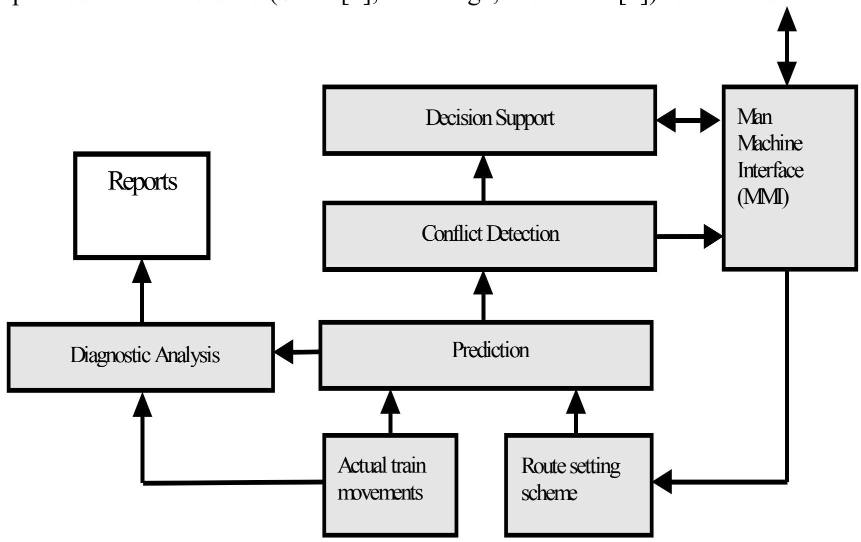

Figure 1: CD/DS System architecture with off-line diagnostic analysis

Predictions

The Predictions entity calculates train movements based on track layout, signals, signs, curves, (temporary) speed limits, train characteristics, etc. The predicted train movements are continuously compared with the reported actual train positions and recalculated, so rendering the predictions as accurate as possible.

The calculations result in a *prediction*, i.e. a collection of predicted time stamps for each train along the infrastructure (e.g. signal passing times, route setting time, etc.).

Diagnostic analysis

The reliability of the reported conflicts depends on the quality (i.e. accuracy and stability) of the predicted train movements. The Diagnostic Analysis entity consists of recording and diagnostic functions, which are utilised to improve the quality of the train movement predictions.

Another important aspect is the quality of the actual execution of the train process. The fluctuations in this process determine the upper limit of prediction quality. Gathering statistical information about the train process itself helps to identify this upper quality limit.

The diagnostic analysis functions present the data in the following analysis models:

1. Accuracy of *predicted* signal passing times.
2. Stability of *predicted* signal passing times.
3. Fluctuations in *measured* running times.
4. Fluctuations in *measured* dwell times.

Models 3. and 4. relate to the actual execution of the train process.
These four models deliver the information required to tune the CD/DS system and to further improve the reliability of conflict detection.

Conflict detection
The Conflict Detection entity detects and reports various types of conflict. The aim of conflict detection is to support the train process supervisor. It is therefore important that conflict reporting be *timely* and *reliable*. *Timely* because a train process supervisor should anticipate the execution of the train process and *reliable* to avoid unnecessary readjustments. Thresholds are set, to prevent conflicts being reported and then removed from the user interface a few moments later. Only those detected conflicts that are independent of other conflicts are reported to the user interface (MMI).

Decision support
The Decision Support entity uses operational research, decision trees and cost functions to resolve the selected conflict and results in a set of adjustments to the route-setting scheme. A new set of predictions is then derived from the adjusted scheme. The selected conflict will then be removed from the MMI.

3 Results of pilot site operation

During 1999, the CD/DS test system was integrated into the operational TRACE system (Renkema & Vas Visser [1]), approved and authorised for pilot site operation. This step in the development process started in December 1999 and is the preparation for a full rollout on Netherlands Railways. It gave the Traffic Control organisation the opportunity to gain an insight into the possibilities of the CD/DS system for their process control operations, to be involved in the choices and decisions regarding further developments and to attune the development of their work patterns to the system.

The main goal of the test was to prove the usefulness the system for the train process supervisors under operational circumstances.

Test system
The test system functions were train movement prediction, diagnostic analysis, conflict detection and decision support. From the train process supervisor's point of view the infrastructure related-conflicts are the most important. The 'conflicting routes' and 'occupied platform' conflicts were therefore tested first.

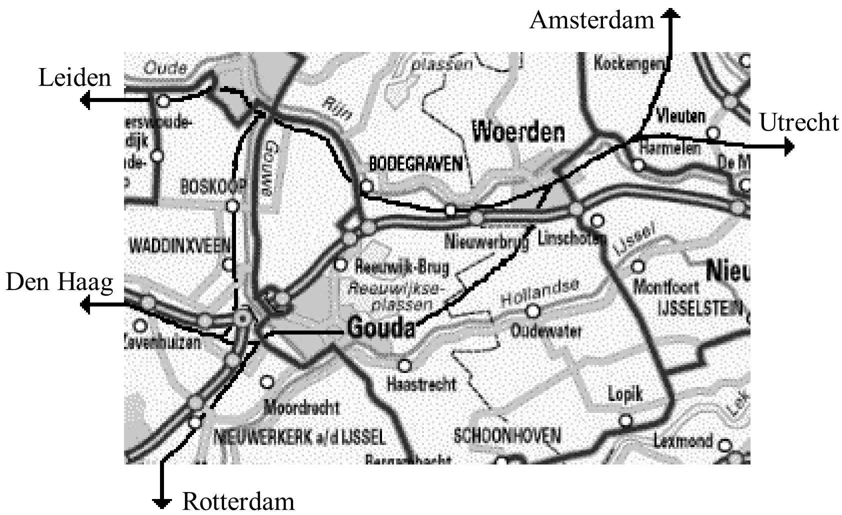

Figure 2: Pilot test site in the western area of the Netherlands

Test area
The selected test area was *near Utrecht*, which is one of the most busy railway nodes in the Netherlands. Gouda, a fairly large station, is situated in the middle of the test area (See Figure 2).
The following infrastructure and train service aspects rendered the area suitable for the tests:

- Double and single track, a number of small stations and one large station (Gouda), enough junctions and a minimum transit time of 20 minutes
- Different types of train service, with high-frequency main and local lines, coupling and splitting of trains and both passenger and freight trains.

Prediction quality
The *goal* is to determine whether the CD/DS technology is capable of predicting train movements under operational circumstances to a quality level sufficient to provide reliable conflict reporting.

The CD/DS system is based on accurate and stable predictions of signal passing times. After two weeks of operation, almost 8 000 predictions were analysed and showed positive results. The *accuracy* of signal passing time predictions is defined by three parameters:

- *Average deviation* between measured and predicted signal passing time
- *Range* of these deviations
- *Actual prediction age*, i.e. the period between the measured signal passing time and the moment of the final prediction.

Table 1 shows the *evaluation criteria* ('Required') and the observed parameter values resulting from analysis of the measured and predicted data for 'all signals' and 'all trains'.

Table 1: Accuracy of signal passing time predictions

	Average deviation	Range	Actual prediction age
Required	< 45 s (15%)	< 60 s (20%)	> 300 s (100%)
Observed	17 s	44 s	545 s

Table 1 shows that almost 10 minutes (545 s) before the train actually passes a signal it can be predicted with an average deviation of 17 s, and that these deviations spread over a range of 44 s. These values are well within the set criteria. The 44 s range also indicates that during the test period the train process was under control.

As well as analysing 'all trains', the diagnostic analysis was performed for each train series. Figure 3 shows the average deviation between measured and predicted signal passing times for trains from Utrecht towards Gouda.

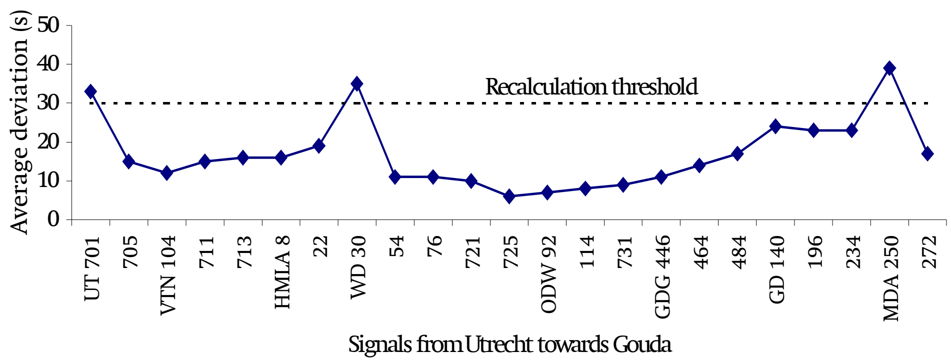

Figure 3: Average deviation between measured and predicted signal passing times

The maximum achievable prediction accuracy is determined by the fluctuations in the measured running times. The actual execution of the train process was therefore analysed to determine these process fluctuations. Figure 4 shows about 100 measured and predicted train running times between two signals near Vleuten. For main line trains as well as for local train, the predicted and measured running times match fairly well.

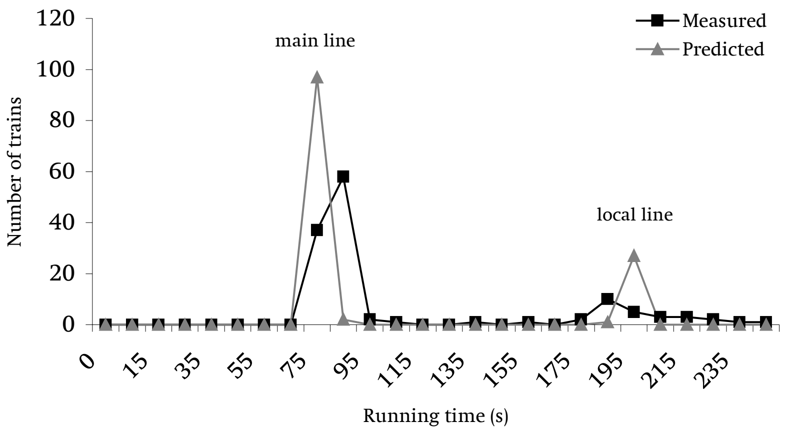

Figure 4: Measured and predicted running times between two signals

Conflict detection

The *goal* is to determine whether the detected route and platform conflicts will give sufficient insight into the operating restrictions on the allocation of infrastructure. Will conflict detection be timely, reliable and stable? Do the detected conflicts match the practical experience of the supervisor?

The *evaluation criteria* are that at least 80% of those conflicts reported within 5 minutes before occurrence lead to restrictions on infrastructure usage, and no more than 20% of restricted infrastructure usage situations go undetected or unreported. It is not easy to judge whether the criteria will be fulfilled, because the supervisor will usually take measures to resolve a conflict. The evaluation was therefore based on the expert judgements of the supervisors involved, who concluded that the criteria were largely fulfilled.

One important result from the test was that for at least half of the reported number of conflicts the supervisor would decide not to solve the conflict. This occurs, for instance, when a passenger train arrives a few minutes too early and conflicts with another arriving or departing train that is on schedule. Another example is a main line train that conflicts with a delayed local train, but which can only pass the local train some stations further down. The drawback of the current system design is that the reported conflicts must be solved, otherwise the supervisor will not be able to see the potential downstream dependent conflicts. This indicates that a more ‘intelligent’ approach to conflict reporting may be needed, such as only reporting conflicts that have to be solved.

Decision support

The *goal* is to determine whether the set of suggested measures adequately covers the measures the supervisor would normally have chosen. Specialists and supervisors set up the set of Decison Support measures in prototyping sessions during the specification phase.

The *evaluation criterion* is that the measures preferred by the supervisor be available in the Decision Support session in at least 95% of all cases. No more than 5% of the resulting plan adjustments may differ from how the supervisor would adjust the plan.

The decision support sessions showed very good *results.* The evaluation criterion (more than 95% coverage) was fulfilled. The supervisors felt the need for one pseudo-measure: ‘ignore the selected conflict ‘(See the results of conflict detection above). Although the decision support functionality was limited (i.e. no detection of subsequent conflicts) the result is valuable.

4 Conclusions

The CD/DS system fulfils the specified expectations and largely satisfies the end-user.

The pilot site test showed that the quality level of train movement predictions based on signal passing time detection is such as to ensure timely and reliable conflict reporting. Conflict detection and decision support functions make it possible for train process supervisors to work under operational conditions at a higher level of abstraction in keeping the route setting scheme up-to-date and to prevent from falling back to manual route setting.

For many conflicts, the train process supervisor would like to be able *not* to adjust the route setting scheme, as it is known from practical experience that those plan adjustments are not needed. This indicates that a more ‘intelligent’ approach to conflict reporting may be required.

References

[1] Renkema, M. & Vas Visser, H. TRACE supervision system for dispatching and passenger information, Proceedings of COMPRAIL, pp 247-256, 1996.

[2] Stolk, A. Automatic conflict detection and decision support for optimal use of railway infrastructure; Purpose and concepts, Proceedings of COMPRAIL, pp 629-638, 1998.

[3] Makkinga, F. & Metselaar, S. Automatic conflict detection and advanced decision support for optimal usage of railway infrastructure: Prototyping and test results, Proceedings of COMPRAIL, pp 907-915, 1998.