Experimental evaluation of decision support tools for train traffic control

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Abstract

To plan and control train traffic constitute very complex tasks. The human being, in the role of train traffic dispatcher, must be able to take fast and correct decisions and effectuate them efficiently. These operators must then also be supported by efficient decision support and control systems. In order to study the involved questions a train traffic simulator (TOPSim) has been developed at Uppsala University in Sweden. With this TOPSim simulator it is possible for a human operator to - in real-time - control the movements of the simulated trains running on a model of an arbitrary railway line. This paper describes the results of our experiments using the first version of the TOPSim simulator, with the focus on questions concerning the computerisation of the re-planning process. Professional train dispatchers have been participating in the experiments presented here. Also the questions of using a decision support tool based on a traditional train traffic simulation program, in the train dispatching process are discussed. These questions have some interesting implications on the traditional use of simulation in the long term planning process.

1 Introduction

Due to the intensified utilisation of the railway network in combination with higher speeds and a mix of different operators, it will in the future be important to have train traffic operators with the adequate knowledge and skills, working in an efficient organisation. These operators must then also be supported by efficient decision support and control systems.

It is an intriguing task developing new control strategies and designing the user interfaces and decision support tools of the control systems, so that the utility and the usability of the system is optimised. Therefore, a train traffic simulator (TOPSim) has been developed at Uppsala University, Dept of Information Technology, Human Computer Interaction, in Sweden, see[10]. This new simulator system is based on the kernel of the previously developed simulation system SIMON/TTS, see [6,7], which has been used by Banverket (the Swedish National Rail Administration) for off-line simulations in the planning processes. The simulator has a modular architecture making it possible to connect external control and presentation
systems.

With this TOPSim simulator it is possible for a human operator to - in real-time - control the movements of the simulated trains running on a model of an arbitrary railway line, see figure 1.

![TOPSim simulator system](image)

Figure 1: The TOPSim simulator system

The main purpose with this simulator is to do experiments with the design of new user interfaces and decision support tools, and to test new control strategies for the train traffic control operators. Therefore an experimental environment - a "control room" - has been designed and created at Uppsala University. In this laboratory it is possible to make the experiments concerning different aspects of the control process.

In this environment it will also be possible to test the usability and usefulness of other support systems for train dispatchers, to evaluate alternative strategies for solving conflicts between interacting trains and in the long run to provide a simulator environment for education and training of train traffic operators.

The main goals of the project are to evaluate our proposed new control strategies, decision support tools, and operator interfaces, see [1,3,4]. The objective of them is to achieve control on a higher and more traffic related level. By doing so, we can move the focus of the work from control of the technical infrastructure, to the continuous reformulation of a functional traffic plan. We call this “control by planning”. The plan, which always must be feasible, is then most often to be automatically executed. In this way the focus is no longer on the real-time control tasks, but more on analyzing the future development of the traffic system, e.g. to identify possible conflicts that can be prevented in advance. Time can be spent on preventing disturbances instead of solving them when they have already occurred. We see two different roles for the future traffic dispatchers. First we have the planner, who has the responsibility for continuously maintaining a feasible traffic plan, and secondly the executor, who takes over when the plan can no longer be automatically executed. The executor manually controls the traffic in a way similar to the one used today.

Decision support tools that support the operator in his work with train traffic disturbances, train conflicts, and the re-planning of the timetable, can be developed and implemented in many different ways. Our effort is to find and implement simple, easy-to-use support functions that can be integrated into the future user interface of the control system. Very important is that the support functions have the potential to be of practical use, especially under disturbed conditions. This research is done in cooperation with professional train dispatchers.

The chosen direction of our work is essentially based on our experiences from previously performed work on CATD algorithms (Computer Aided Train Dispatching), i.e. re-planning algorithms, see [2]. But it has also direct links to an ongoing project in which train drivers, dispatchers, and people responsible for timetable planning are directly involved, see [3,4].
This paper describes the results of our experiments using the first version of the TOPSim simulator, with the focus on questions concerning the computerisation of the re-planning process. Professional train dispatchers have been participating in the experiments presented here.

Also the questions of using a decision support tool based on a traditional train traffic simulation program, in the train dispatching process are discussed. These questions have some interesting implications on the traditional use of simulation in the long term planning process.

2 Important issues

In this paper we are focusing on a few, but important issues related to the real-time re-planning task of the train dispatching process, i.e. the making of a new plan in case of disturbances disrupting the original one. Being in a process involving computerisation of tasks that earlier has been more or less fully handled by humans, it is important to try to find what the typically - normally hidden - human aspects are.

2.1 The re-planning task

What strategies do the human dispatchers use in the re-planning task? Are there great differences between how individual dispatchers solve a problem? Is it possible to find a “best” solution for a specific problem?

2.2 Computerisation of the re-planning task

What are the opinions of the dispatchers on this issue? Are they willing to change from making the plan with a pencil on a time-distance diagram on paper to making it with the mouse on a computer screen?

2.3 The “built in”-dispatcher of a traditional train traffic simulation program

How good is the “built in”-dispatcher of a traditional train traffic simulation program in comparison to a professional human dispatcher? What is the effect of “its” skill on the results of using simulation in the long term planning process?

3 Our Decision Support Systems (DSS) approach

The DSS that we propose is to support the dispatcher in the decision-making processes during train traffic control tasks. In short, the main purpose of our DSS tool is to aid a decision-maker to gain a greater understanding of his tasks and thereby help him to find a solution (i.e. plan) that is good enough. Of course it must also facilitate the actual making of the new plan.

We have in order to find appropriate models made a survey of how the dispatchers actually handle the process of conflict solution and re-planning. The main conclusion of this survey was that when the dispatcher is about to make a new plan, instead of solving the embedded conflicts in order of time, he is using a simplifying strategy based on prioritising to certain trains. That is, by solving some of the major conflicts the overall complexity of the problem is drastically reduced. The details of this survey, as well as its results are presented in [1].

To start with we are concentrating on tools supporting the solution of conflicts and the timetable re-planning stages. The development and implementation of the tools are done in an iterative process, in cooperation with professional dispatchers.
4 Performed experiment

4.1 Background

The paper graph with the timetables for the trains is still one of the most important tools that train dispatchers use in their everyday work. Controlling train traffic in Sweden today involves interacting with several different systems, building an overall picture of the current situation and taking appropriate actions. The train dispatcher has a mental model, a representation in the mind over the traffic process. It is important that this model closely resembles how the traffic process works in reality. If the mental model deviates from the reality there are greater risks for inappropriate actions by the dispatcher. With more experience the human operators’ mental model improves and predicting the outcome of an action or the effect of a disturbance gets easier. However, our studies show that disturbances often occur in the near future which drastically increase the difficulty and also makes it harder to obtain a correct model of the situation. Just mapping the traditional paper graph to a computer would hardly improve the work situation. To achieve improvement a computer based graph should provide a set of well designed tools that supports the maintenance of an accurate mental model of the situation. With the appropriate tools at hand the train traffic controller would gain better situation awareness and also be supported in making correct decisions. This experiment is the first in a series of experiment that will evaluate and test the usefulness of our proposed computer based graph.

4.2 Aim

In order to be able to do valuable complex experiments on train traffic control in the future, there is a need for relevant traffic scenarios/problems. Not only do we need the scenarios but also preferably some kind of best solution to the scenario so that it is possible to evaluate the outcome. The aim of this experiment was to find out if the scenario used in the experiment is a relevant one and what the best solution to that specific problem would be. Another purpose was to look at how re-planning tasks are performed and if there are great individual differences in solutions between train dispatchers. Yet another aim was also to investigate human computer interaction aspects of the computer based graph, but that analysis is beyond the scope of this paper.

4.3 Test Case

Train traffic controllers participating in the study were presented with a task to solve a problem and generate a new valid functional plan as to how the train traffic could be carried out. Their goal was to do this and at the same time minimise the total sum of primary and secondary delays.

The setup used during the experiment was limited to considering traffic during two hours and over a single track line with ten stations.

![Figure 2: The single track line Storvik-Borlange (simplified track layout).](image)
Train 410 experiences technical problems at 7.12pm and stops at “Hinsnoret”, a station with one siding. After three minutes at 7.15pm the train driver calls the train traffic controller and informs her that the problem will be taken care of in seven minutes and that the train will be ready for departure at 7.22pm. During the 10 minutes of the technical problem one of these tracks is thereby occupied. At 7.15 the train 9070 has already passed the “Ornas” station and it is thereby not possible to hold that train there. This scenario causes disruptions that the test subject has to try to solve. Train traffic controllers were told to prioritise all trains the same way. The focus of this test is only the traffic running on this line; there was no need to take into consideration surrounding traffic. The instructions and information provided to the test subjects were detailed in order to, as much as possible, avoid that they would use their preconceptions about train traffic in this specific case. I.e. prioritise trains differently.

4.4 Realization of experiment

All the tests were conducted on site with train traffic controllers from the same train traffic control centre, DLC Gavle. A total number of 12 dispatchers participated in the experiment. Of these 12, 8 dispatchers performed the experiment with a computer based graph. This graph was limited to the fact that interaction was restricted to adding, removing or changing the duration of stops. I.e. it was not possible to re-plan the speed at which a train should travel or its planned track usage. To record important measurements during parts of the experiment concerning the computer based graph results were logged by the system and all interaction with the user interface was recorded by screen capturing software. These schemes provided us with the possibility to backtrack and re-evaluate the experiments in a very nice manner. The other four (4) dispatchers solved the same problem, under the same pre-conditions, but instead of using the computer based time-graph they worked with a traditional paper time-distance graph. The paper graph was of the same kind as they are accustomed to use in their everyday work.

Each experiment started with a short introduction of the project and a description of the developed system. Since some train traffic controllers were to solve the problem using a computer based graph, they were given a shorter training and introduction session on how to interact with, and on how to use the system. All test subjects were presented with the same set of pre-conditions explaining the problem and delimitations. The experiment started with the

![Figure 3: Computer based time-distance graph with test case introduced.](image-url)
test-coordinator introducing the problem into the test environment, then letting the test subject perform the experiment. There was no time limit to the test, instead the train dispatcher was allowed to work until they felt that they had reached a satisfying solution. During the experiment “Think-aloud” was used, this means that operators were asked to think aloud and verbalize their thoughts as they interacted with the system. By using this method it was possible to get a more detailed idea on how and why certain measures were taken by the operator. After completion of the re-planning task the test subjects that had been using the computer based graph answered a questionnaire.

4.5 Results

A majority, nine (*) out of twelve of the train dispatchers solved the scenario in much the same way. What characterises this solution is that a “three-train meeting” is used to solve the primary disturbance. This means that since the station at Hinsnoret (HNO) only has one siding, one train waits outside the station area until the train occupying one of the stations tracks leaves. It is then possible for the waiting train to proceed and thereby clearing the track so that the other train on the station can depart. The variance in the number of minutes in the delay between these solutions comes from the fact that different train dispatchers plan the traffic with different amounts of time marginal. In comparison to other solutions this main solution appears to be the best one, considering the pre-conditions.

<table>
<thead>
<tr>
<th>Train dispatcher</th>
<th>Result Total delay[min]</th>
<th>Planning utility</th>
<th>Experience in train traffic control [years]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34 *</td>
<td>Computerbased</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>49</td>
<td>Computerbased</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>23 *</td>
<td>Computerbased</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>23 *</td>
<td>Computerbased</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>39</td>
<td>Computerbased</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>31 *</td>
<td>Computerbased</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>35 *</td>
<td>Computerbased</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>23 *</td>
<td>Computerbased</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>27</td>
<td>paperbased</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>25 *</td>
<td>paperbased</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>28 *</td>
<td>paperbased</td>
<td>14</td>
</tr>
<tr>
<td>12</td>
<td>N/A**(**)</td>
<td>paperbased</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1: The results of the experiment.

The result of train dispatcher number 12 (**) is not applicable since the re-planning task did not result in a valid plan.

To comment on the relevancy of the problem/scenario used in the study, train traffic controllers responded that the scenario introduced is something that could, and sometimes does happen. So the scenario is considered to be relevant. The best solution according to the study would be the so called “three-train meeting”- solution (see fig 4). It is important to remember that this solution only is the best one under mentioned pre-conditions and not necessarily in real life. However, confronted with the question if they would use this solution in real life all of the dispatchers using the three-train meeting said that they would do so. Two of the train dispatchers with alternative solutions said that they would not perform the three-train meeting due to the fact that if anything else went wrong during this meeting consequences would be expensive in terms of delays and cancelled traffic.

The train dispatcher’s opinions on computerising the timetable graph are predominantly positive. However it is too early to say if they are willing to change from using paper graph
into using a computer based graph until further issues are resolved, such as limitations in functionality and training etc.

Figure 4: Dispatcher number 3’s solution, a “three-train meeting”.

5 Using a traditional train traffic simulation program on the same case

5.1 Background

SIMON/TTS is a train traffic simulation program developed by Banverket in Sweden. Normally it is used to make “batch”-simulations of the train traffic of some railway net. These simulations are the base for different calculations of capacity measures that are used to make comparisons between different investment alternatives, see [6,7,8]. A common method is the following:

1. Decide what kind of and when stochastic disturbances are to be introduced.
2. Make simulations with stochastic disturbances introduced according to above. Do that for all alternatives.
3. Measure for example the average total delay time for each of the alternatives.
4. Compare the results of the different alternatives. Etc.

Experiences of using the described method, especially on single track or lines with different train speeds, are that the results are affected of “the behaviour” of the “built in dispatcher” of the simulation program. Sometimes “it” makes really bad decisions and occasionally it is unable to fulfil its tasks. I.e. some kind of deadlock occurs. This problem is dealt with by making the assumption that it hopefully behaves the same way for all alternatives.

Modelling the behaviour of a dispatcher is of course difficult – it is a complex artificial intelligence problem - but we feel that there is a need of “dispatcher model” that is relatively simple, transparent and give solutions that is, if not optimal, good enough.

We want to point out this particular issue now that we are beginning to have a tool that makes it possible to do more profound studies of the involved questions.
5.2 Simulation of the case

We have used SIMON/TTS to make a simulation of the same case as above. Only one simulation has been done this time. For the moment we will just point out this important question and the possibilities embedded in the TOPSim simulator that we have created. In future work we will look deeper into the problems of the “built in” dispatcher model.

There are some input parameters that affects the behaviour of the “built in”-dispatcher of SIMON/TTS. We have set them according to their “default-values”, see Appendix. In the input timetable we also set the same priority on all trains, precisely as in the instruction to the human dispatchers in the experiment case described above.

5.3 Result

The time-distance diagram (graph) from a simulation of the actual case – with no disturbances - can be seen in figure 5. The dashed line shows the original timetable and the straight line shows the actual running of the trains. As you can see the trains are run almost precisely according to the plan. For a few trains there are minor slacks resulting in arrivals to the final destiny slightly before the planned arrival time.
Before running the disturbed case we instructed SIMON/TTS to stop train 410 for three
minutes in station HNO and at that time to give it a so called “input delay” of seven (7)
minutes. That is, we introduced the same disturbance as in the case above.

Figure 6 shows how the SIMON/TTS handles the case. SIMON/TTS finds a solution that
differs quite a lot from the solutions made by the humans. It lets train 9070 perform a passing
of train 410 at station HNO and thereby introduces quite large delays on train 410 and meeting
train 849. It later also conducts two (somewhat peculiar) passings at stations FLN and HNO
between trains 7591 and 9110. The value of the total delay is in this case 29 minutes, i.e. 6
minutes more than the best human solution.

In this particular case SIMON/TTS found a solution that was clearly less good than the ones
produced by the majority of the human dispatchers. But as this test case happened to give the
humans the opportunity to use “non-standard” methods in order to find a good solution, we
think that SIMON/TTS (this time) did his job pretty well.

Figure 6: The original plan (dashed) and the simulated running of the
trains in the disturbed case.

6 Conclusions

Our experiment has given us some important answers, but of course also new questions. The
chosen scenario of the task case was considered relevant, even though it was not a standard
type problem scenario, as we thought before the experiment was done. All dispatchers did not
agree on using the so called “three-train meeting”- solution in real life.
The train dispatchers were predominantly positive on computerising the timetable graph, but it is too early to say if they are willing to change from using paper graph into using a computer based graph until further important issues are resolved.

In earlier studies we have found that the dispatchers in making their plans use other margins, regulations and rules of thumb than planners and timetable constructors do, see [2]. The so called “three train meeting” that they used to solve our test case is yet another example of that. This type of meeting is normally not included in existing train dispatching algorithms, neither used by the timetable constructors, it is considered to hazardous. But a human that has a good overall picture could be willing to take the risks, and thereby gain important minutes for the involved trains.

We have also indicated the problems with “the behaviour” of the “built in dispatcher” of a traditional train traffic simulation program and its effects on the simulation results. We will soon return to these questions.

The performed experiments have proven to be useful in producing valuable knowledge about how human controllers make their decisions and how they judge uncertainty in disturbed traffic situations. Therefore we will continue our research on train control by further developing our TOPSim simulator, thereby be able to enhance the complexity of our future experiments, and hopefully produce more interesting research results.

7 Acknowledgements

This project has been financially supported by the Swedish National Rail Administration.

8 References

Appendix

The version SIMON/TTS used in the described case was 4.25 Beta 7.

The input parameters that effects the behaviour of the “built in”-dispatcher of SIMON/TTS was set according to the following list:

- prio_grns 1
- tidig_grns 4
- prio_just 4
- magasin 1
- tdkmetod 0
- tdt_marginal 0
- forarmarg_tdt 1