Decision support in the train dispatching process

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Abstract
One key area has received special attention in Sweden and that is the role and working environment of the operators, e.g. the train dispatchers. It will in the future be important to have operators with the adequate knowledge and skills, working in an efficient organisation. The operators must also be supported by adaptable and adequately designed decision support and control systems. The emphasis in this paper is on decision support in the train traffic control centre. The goal is to develop and evaluate, simple, easy to use support tools. Support tools that must have the potential to be of practical use. In order to reach this goal it has been necessary to make a survey of how the dispatchers actually handle the process of conflict solution and re-planning. This work, as well as its results is presented in this paper. Furthermore is the design of the decision support tool to be implemented briefly described.

1 Introduction
The railway industry is in a renaissance period of modernisation, caused by the rapid technological developments, the environmental needs, the ageing of existing equipment, the need to cater for both the current and the future transportation requirements, and – of course – the present European political processes.

One key area has in this sense received special attention in Sweden and that is the role and working environment of the operators, e.g. the train dispatchers. It
will in the future be important to have operators with the adequate knowledge and skills, working in an efficient organisation. The operators must also be supported by efficient decision support and control systems. Experiences from the field of process control have shown difficulties in designing the user interfaces and decision support tools of the control systems, so that the utility and the usability of the system is optimised.

Two interdependent projects, named TOPSim and CATD respectively, are currently running in Sweden. The main objective of the TOPSim project is to create a Train traffic Operation and Planning SIMulator that is intended to be used in the development and evaluation of decision support systems (DSS) and human-machine interfaces (HMI) for future train control systems. The aim of the CATD project (Computer-Aided Train Dispatching) is to formulate requirements for the TOPSim simulator as well as develop, implement, test, and evaluate new decision support tools and human-machine interfaces.

The emphasis in this paper is on decision support in the train traffic control centre. Our goal is in the short run twofold. First, to map out how dispatchers work. Second, to develop simple, easy to use and practicable support tools. Which here means that they must fit within the limitations of the actual system, the budget, and also have the potential to be of practical use. Within the framework of the CATD project, two decision support tools are planned to be developed and implemented in the environment of the TOPSim simulator. The survey of the dispatchers’ conflict solution and re-planning processes, as well as the proposed support tools are presented in this paper.

2 Presentation of the problem

2.1 Disturbances
The fundamental problem of the train control process in Sweden (as well as in many other countries) is the multitude of disturbances of different kinds occurring almost all the time. Most of these disturbances cause both directly and indirectly delays in the railway traffic. There are many different factors causing disturbances, most of them are of technical and organisational art. The delays caused by a certain disturbance can be divided into primary and secondary delays. The primary delays are a direct effect of the actual disturbance, while the secondary are the delays of the trains that interact with the primary delayed trains, see for example [4].

2.2 The re-planning process
The train dispatcher, who from a train traffic control centre plans, supervises, and controls the movements of the trains cause only a diminutive part of the total quantity of primary delays, but has a key role regarding the secondary delays. By making changes in the original plan (timetable) the dispatcher tries to handle the effects of the disturbances, i.e. by changing the times and locations for the trains.
meetings and the train overtakes he tries to minimise the secondary delays. This re-planning process is a demanding task due to the great complexity of the system. The fact that the information needed to control the system varies in quality does not make it easier. Today it is based on mainly manual methods and rules of thumb. See [4] for more details. Another interesting subject here is how the fact that train positions today are known only at discrete points of time, really effects the possibilities to control the train traffic.

2.3 Decision support in the re-planning process
We have in previous work shown that there is a potential for improvements in the train control process and thereby better on-time performance, see [4]. There are probably several ways to do this. We have chosen to concentrate our effort to the introduction of computerised decision support tools, new user interfaces in the control centre, and the organisation of the control work. This paper deals with the decision support aspects. The user interface aspects are described in another paper, see [9].

Theoretically, a decision support system for train control could be based on an optimisation model minimising the total, weighted delays. In a former study, we have analysed so called algorithms for computer-aided train dispatching. In this study we found, among other things that “It is difficult, not to say impossible, to incorporate all relevant aspects of a work task like this in a model. As described there exists to many uncertainties, especially in disturbed situations.”, see [4] for further details.

Our belief is that, to start with a decision support system must be based on a model that supports the dispatcher in his solution process, and not on a model that produces an already solution. It is also important that the model is made completely controllable and transparent to the user. Last but not least, it must be possible to find the solution with aid of the DSS within the actual time limits set by this real-time environment.

3 Decision Support Systems (DSS) and Dynamic Decision Making (DDM)

3.1 What is to be learned from the DSS community?
In order to learn more about decision making and how to design and implement a DSS we have made an outline of what is written and taught within the DSS community, see [8]. In short, the DSS research gives us a general framework, discussing decision making, giving the prerequisites for good decision making as well as defining what constitutes a decision support system. In the following we are – from a train control perspective - summarising what we found.

As everyone knows it is difficult to make good decisions? Clemen [11] points out four determining factors, all of them relevant in the process of train control. First and foremost is the complexity of the task. This factor is also mentioned by Simon [10] who has stated that there is a “… growing realization that coping with complexity is central to human decision making ...”. A human being has a
limited ability to perceive and solve complex problems, and therefore builds simplified mental models of the real situations. And even if these models are used in a rational way, the simplification leads to less good decisions being made. It is for example, impossible for a dispatcher to keep a full check on all trains moving around in the net and predict and control their future behaviour. The second factor is the uncertainty in the situation. How fast is that particular train running? A third factor that the decision-maker has to consider is that there often are several different goals involved. A decision that is correct in the short view may be wrong in the long view and vice versa. Finally, different perspectives may lead to different conclusions, especially when several people are involved in the decision process. Lenior [12] as well as others [4,5,6] has given clear examples of the influence of the last two factors in the train control process.

Therefore, a decision-maker, in order to be able to make good decisions must be informed, have access to good models, and also have access to the “right” information. Here model ranges from simple, implicit ones to sophisticated mathematical models or computer programs. One way to reach this goal is to introduce a DSS. A DSS is in general terms a computer-based, interactive system that collects the necessary information from different sources and gives the user assistance in the organisation and utilisation of the information. Often it also makes it possible for the user to analyse and evaluate the different decision alternatives by using built-in models.

In the DSS research society it is generally agreed that a DSS has three main components, namely the DBMS (Database Management System), the MBMS (Model-base Management System), and the UI (User Interface). The DBMS collects, organises, and gives the user access to data. The MBMS handles the use of the models that is part of the system. Finally, the UI, which to the user “is” the actual DSS, takes care of all interaction between the user and the other parts of the system.

Unfortunately the DSS community seems to be too ingratiating and concerned with issues concerning “executives” and their decision support. We found almost nothing about real-time decision making in the DSS literature. Therefore we have also begun applying knowledge from a less developed but important research area, Dynamic Decision Making. This area is briefly described in the next section.

3.2 Dynamic Decision Making (DDM)

Dynamic Decision Making (DDM) is a subfield within the area of decision making. Brehmer [2] has given a definition of DDM, and following that one we can see that the control work facing a dispatcher has exactly the characteristics of DDM:

1. A series of decisions is required to reach the goal.
2. The decisions are interdependent.
3. The state of the system changes, both autonomously and as a consequence of the actions of the decision maker.
4. The decisions have to be made in real-time.
Brehmer has also stated that it is not feasible to analyze dynamic decision problems in terms of classical decision theory. Therefore an alternative framework is developed, based on systems analysis and control theory, see [3,6]. According to this, there are four requirements that must be fulfilled in order to control a system of this kind:

1. There must be a goal.
2. It must be possible to observe the state of the system.
3. It must be possible to alter the state of the system in order to control it.
4. There must be models of the system (including the operators’ mental models).

Strictly using these four requirements on the train control problem, affects not only the design of the DSS, but also almost all other equipment, such as information systems, control and signal systems and their user interfaces and so on.

We have started using the general findings from the DDM research in our context, and will continue to do so in the design as well as in the evaluation of our DSS.

3.3 Our DSS approach

The DSS that we propose is to be used to support the dispatcher in the decision-making processes that exists in the train traffic control task. To start with we concentrate on supporting the conflict solution and timetable re-planning stages. In short, the main purpose of our decision support system (DSS) is to aid a decision-maker to gain a greater understanding of his tasks and thereby help him to find a solution that is good enough.

In order to find appropriate models it was necessary to make a survey of how the dispatchers actually handles the process of conflict solution and re-planning. This work, as well as its results is presented in the next chapter.

4 Development through cooperation

4.1 Background

During the analysis phase of the development of DSS-tools for train dispatching, we found the need for and the necessity to cooperate with professional train dispatchers. The purpose was to get immediate feedback of our ideas and to better understand the dispatching-process itself and, perhaps most important, how decisions are made by the operators while dealing with conflicts of minor or medium complexity. Our belief was that such cooperation would evidently reduce the chances to design a DSS-tool that was “wrong” for its purpose.

FTTS, a cooperation project between Banverket and Uppsala University, dept. of HMI, started in 1996 with focus on future control systems and user interfaces for train traffic dispatching. Project members have been experts from the train traffic planning and dispatching area as well as researchers from Uppsala University. Within this, a workgroup was formed to handle the project tasks. The CATD-
project was in early 2001 invited to join the sessions of this workgroup, which showed out to be very fruitful concerning the proceedings of the research work within the CATD project.

4.2 Cooperation
Primarily, the main task was to collect information about how the operators at the Train Traffic Control Centre (TCC) “work”, i.e. actually handles the process of conflict solution and re-planning when disturbances appear. The aim of this analysis was to try to find a proper description of how the basic functions of the DSS-tool should work and how it was supposed to be used by the operators. Detailed interface design was not considered as a primary task at this early stage.

4.3 Method of cooperation
Information from earlier work group meetings concerning their view of a future DSS-tool within the TCC, together with our own experience from earlier performed research work [4, 7], made it possible to form and introduce our first idea of a possible DSS-tool. The methods used to introduce our ideas and theories have mainly been based on seminars. Before each seminar one of the experts prepared a realistic scenario based on a real case study involving different types of conflicts (e.g. delays caused by engine malfunctions, lack of resources etc) on single or double track lines. These scenarios have been of both complex as well as less complex nature. The person responsible for the scenario also prepared and presented a proposed solution to the conflict/s in a way that the scenario would have been taken care of by an operator at the TCC today. The next step during such a seminar was to look at the scenario again but now assuming that we had a DSS-tool to aid us during the process and afterwards, through discussions, try to highlight benefits or disadvantages. The immediate feedback from the expert group, which was of outmost importance, also gave us a clear indication whether this “tool” seemed to be used in a proper way or not in relation to how an operator would have acted in this scenario.

4.4 Decision handling within the TCC
According to earlier work group meetings, a proper and useful DSS-tool seems to have a natural place within the dispatching process, as they say, “taking decisions are really one of the main tasks to deal with as a train dispatcher. When the process is running smoothly you can be more “relaxed” and rely on built in automatic functionalities”. All decisions in the TCC are taken in a dynamic, event-driven, environment that put into focus some factors that are aggravating circumstances during the process of decision making:
1. Time. Do I have enough time to re-plan at all? Do I have enough time to put quality into the re-plan?
2. The extent of the conflict. How complex is the disturbance? Do I have all necessary information to take decisions with quality? Can I take any action at all at this moment with this information at hand?
3. Unreliable information. The given information describing the situation, can it really be trusted? What is the correct position of that train? Actual speed? The purpose of a “good” DSS-tool is to make the process of decision making clearer and less complex to the operator. The tool should give him the ability to contribute with analyses of the current situation and to make prognostications of the nearby future. It is underlined both by the experts within the workgroup and by earlier research [13] the importance that the tool must not interfere with the dispatchers cognitive process while making decisions. A “good” DSS-tool must also bear in mind that all conflict solving takes place in a dynamic real-time environment where nothing within the process stops and wait for decisions to be taken, but will hopefully react to the effects of a decision while executed

4.5 Demands on a DSS from the TCC
Earlier work group meetings also have indicated ideas from the experts how a tool should be designed to meet their expectations. In brief the tool should be able to:
• Identify/detect the source of a conflict and subsequent conflicts, or give attention to the operator that a conflict-situation is likely to happen.
• Detect possible solutions, give proposals of alternative solutions and be able to prognosticate the effects of alternative solutions.
• Have a forward time-horizon that makes it possible to re-plan efficient.

Psychological studies and research within the area of control-theory, see [1], shows the importance of displaying continuous dynamic information about the progress of the process as a function of time, along with prognostications of the near future development. This gives the operator the opportunity to act preventive. Field studies [1] also shows that the operators prefer to supervise the process rather intense and want to be provided with continuous information about the dynamic status of the system. The only possible way to maintain control over a conflict situation today is to continuously keep track of the progress by drawing the changes/development into the TD-diagram (the paper-graph). With access to a good DSS-tool the operator should be able to supervise the train dispatching process in a more controlled way, not letting “minor objects” pass unattended to which, in a prolongation, might lead into a situation where a potential disturbance becomes a fact, or a actual disturbance becomes even worse.

4.6 A first hypothesis
After a couple of seminars during which we had put forward our first proposals of a DSS-tool, we felt rather confident about the basic use of the tool. This made us formulate a first hypothesis concerning how the operators take action during a conflict situation: “The operator starts from the present time line and subsequently solve the conflicts, as they appear, in order of time”. This hypothesis was, except from the results from the seminars, based on our own natural feeling that “it sounds like a proper way to act in such situations” when
dealing with conflicts in a time scheduled plan (this is typically the way optimising algorithms are working too) but also on some statements made during earlier workgroup meetings describing what kind of strategies normally are used within the TCC to handle conflicts:

1. Carry out decisions where it is most urgent according to the time factor.
2. Create and maintain scope for actions (try to gain time).
3. Do not lock or block resources.
4. All flows must be restored as quickly as possible.

4.7 A second hypothesis

After a sequence of seminars we came to a point where we realized that our first hypothesis no longer was relevant. Concurrently with increasing complexity of the scenarios it became more and more obvious that the first statement was not in accordance with the operators way of thinking and acting when the situation of the disturbance was becoming more complex. The dispatchers within the workgroup came to the conclusion that it is impossible to think in terms of time-order, instead they nearly always, by pure instinct use a strategy based on priority as a starting-point. Our hypothesis then was reformulated into: “The operator nearly always uses a strategy based on priority as a starting point when solving conflicts”.

4.8 Results

This new hypothesis made it necessary to repeat some of the scenarios once more and apply the “virtual” DSS-tool on these once again from this new viewpoint. The result from this was very interesting. It gave a completely different pattern in the conflict solving process but, most important, it showed us a pattern of behaviour that was a direct reflection of how the operators really are thinking and acting in “real life” at the TCC. The priority based strategy means that the operator will select one or more trains and simply favour them by giving them a “free way” and then take care of all other subsequent conflicts in a priority based way of acting as well. In other words, the operators handle complexity by choosing to give priority (i.e. “simplify the problem”) and by this action greatly reduce the number of possible solutions.

What knowledge have we gained from this cooperative development?

- It has shown the importance to involve experts during an early stage of a developmental phase. It is very easy to rely on thoughts/belief from own experience while doing design work. By putting a cooperative development environment into practice one opens for much better solutions where experience from both sides, i.e. dispatchers and researchers, will be attended to and put into the design process in order to get a good tool that is of practical use to the operators. By being “forced” to thoroughly go through the “basic design process”, we were also given a much better knowledge of the model, before moving on to the next design-stage.
4.9 Design of the proposed DSS-tool

At this point we new that the work done so far, had given us a solid base for further design. Trying to meet the “demands” concerning the information-ergonomics, the proposed design consisted broadly of five working modes:

1. “Normal”: Showing the present timetable together with actual dynamic movements of the trains.
2. “Prognostication of single train”: The operator can get a prognosis of the future progress of a single train.
3. “Prognostication of multi trains”: The operator can get a prognosis for all, at present time, “visible” trains.
4. “Conflict detection”: All conflicts within the “visible horizon” will be detected and indicated by a red flashing circle.
5. “Alteration”: The operator will be able to dynamically alter a “working copy” of the present (“valid”) timetable, i.e. to change arrival/departure times for a selected train, in purpose to “test” a proposed decision. The tool will recalculate the status and detect possible remaining conflicts or new ones caused by the re-plan action. If a solution is found to be satisfactory, the original timetable can be overwritten by the “working copy”.

5 Conclusions

It is of outmost importance to use the skill of the operators while developing DSS-tools. Providing them, to start with, with tools that are easy to use and supports the dispatchers in their efforts to control the train traffic makes it easier to evaluate the tools for further development. Neglecting to take their skills and experience into consideration may easily lead to a DSS-tool that in the end is not accepted by the prospective users. Working in the way that is described above, we think that the function of the proposed tool is reasonably anchored.

We have found that the DSS society does not cover real-time decision making in this (any) context. Therefore we find it both necessary and promising to begin using the knowledge that is emerging from within the Dynamic Decision Making research area. This is a process that is just started, and it will be very interesting to follow the effects of this, while gradually introduced into our research work.

It is also interesting to note that this cooperation has remarkable increased our base of knowledge concerning the process of decision making within the TCC. Our new hypothesis, that the dispatchers using a simplifying strategy based on giving priority to certain trains, is perhaps the most important of our findings. The work with scenarios in the group with experts on train traffic control, showed that our first hypothesis, that they solve the conflicts in time order, was wrong.

In our coming work we will implement and evaluate the here proposed DSS.
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References
