Taking Driver Advisory Systems to the next level

Per Leander [1)], Andreas Törnblom
Transrail Sweden AB
Västmannagatan 3, 111 24 Stockholm, Sweden
[1] E-mail: per.leander@transrail.se, Phone: +46 (0) 70 511 80 69

Abstract
There is constantly increasing pressure on railways globally to provide greater capacity and improved service performance, whilst reducing investment, operational and energy costs. This drives demand for improved traffic management and train operation systems.

Driver Advisory Systems (DAS) is a fairly new technology within railway/metro operations where Transrail Sweden AB has developed and markets a product called CATO. The technology gives very strong support to increased punctuality, increased traffic capacity and reduced operational cost (e.g. reduced energy consumption). In fact, the system can be used for Intelligent Cruise Control and for highly efficient ATO operation, better than the systems found on the market today.

This paper brings a description/outline of the technology and development trends beyond current standalone Driver Advisory Systems, i.e. C-DAS, Intelligent Cruise Control (ICC) and usage of the technology for ATO.

Keywords
Driver Advisory System, C-DAS, Intelligent Cruise Control, ATO, Sustainability

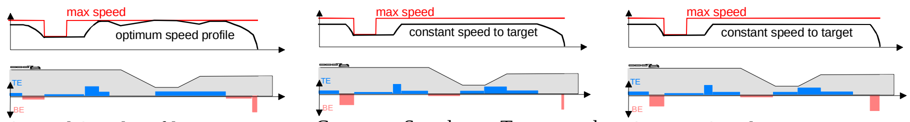
1 Problem and Objectives

There is constantly increasing pressure on railways globally to provide greater capacity and improved service performance, whilst reducing investment, operational and energy costs. This drives demand for improved traffic management and train operation systems.

Driver Advisory Systems (DAS) are finding favour around the world as a means of optimising the performance of individual trains to reduce energy consumption while ensuring close adherence to the timetable.

The definition of a DAS system: A system that assists a train driver to drive on time and with an economic driving style.

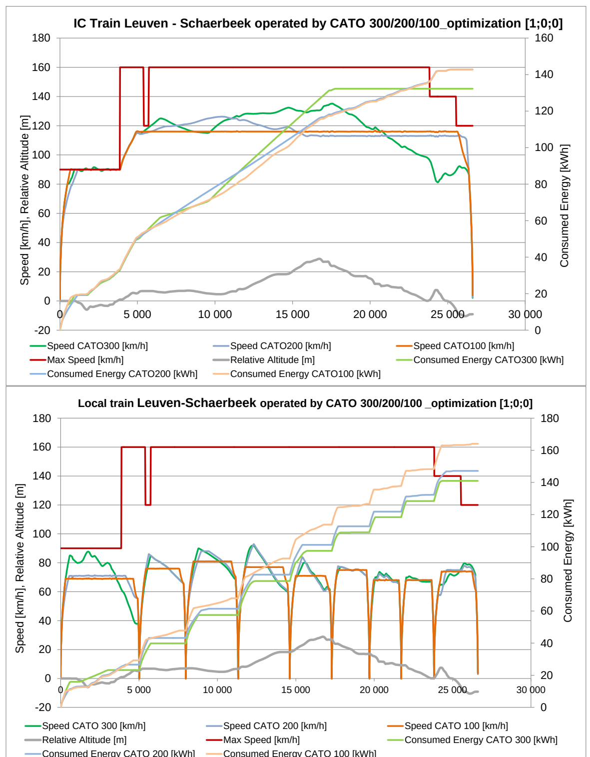
The performances vary between DAS products and depend on the strategies on which they build as well as how they are implemented. For example; if you know the distance to the next stop and the arrival time, a simple strategy would be to calculate the constant speed to arrive on time. You may understand that the issue of efficient driving is far more complex than using this simple strategy. The driving profile shall for example be calculated depending on the track profile (speed limits, gradients, curves), the train (weight, length, motoring/braking performance etc) as well as possible timing restrictions along the journey. Some alternative DAS strategies are presented in Figure 1. The Optimal Speed Profile (CATO300) makes full use of a train's character as a roller coaster.



Optimal Speed Profile (CATO300) | Constant Speed to Target and coasting (CATO200) | Constant Speed to Target (CATO100)

Figure 1: Typical DAS strategies, also available as CATO DAS versions

The difference between the strategies might not appear very substantial, but Figure 2 and Figure 3 illustrate their performances as regards energy savings. Their improvements as regards reduced friction brake energy are even larger.



Train type	CATO version	Min Run Time [min]	Run Time [Min]	Consumed Energy [kWh]	Dynamic Brake Energy [kWh]	Friction Brake Energy [kWh]
IC train	CATO300	12,4	15,0	132,3	7,3	7,3
	CATO200			142,8	9,1	11,4
	CATO100			142,8	12,9	7,8
Local train	CATO300	20,5	25,6	141,0	17,4	39,1
	CATO200			147,2	20,6	40,6
	CATO100			164,1	33,2	41,0

Figure 2: Example of performances of various DAS strategies in IC and Local train operation over a line.

Figure 3 shows the result of a CATO300 Benefit Analysis for the Stockholm commuter train operation.

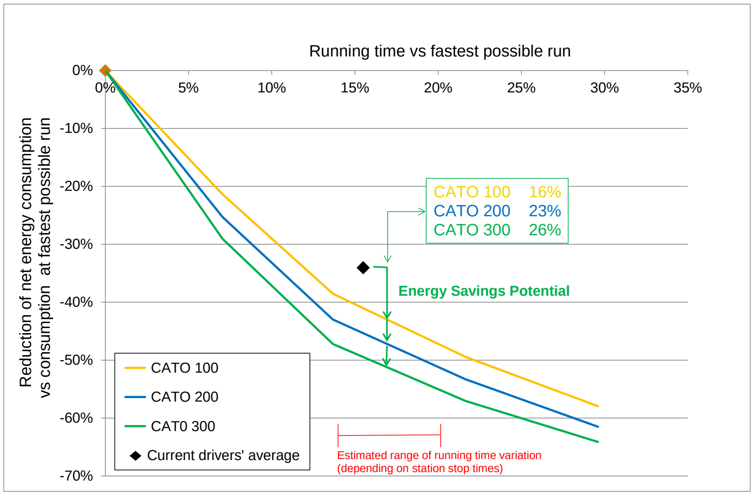
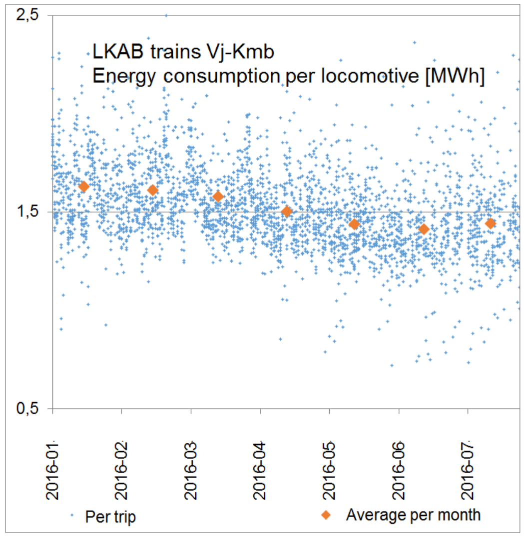


Figure 3: Performance Diagram showing the saving potentials of the various CATO versions in Stockholm commuter traffic. The X-axis corresponds to "slack" e.g. runtime above minimum runtime (MRT). The Y-axis shows energy savings. With more slack increased savings can be achieved. Drivers' average is the black square.

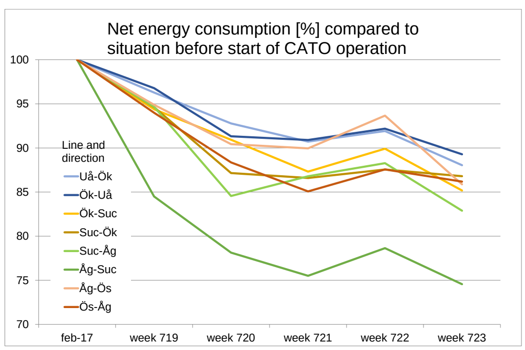
CATO makes use of an optimisation based on achieving the targeted arrival time and minimising a cost function, which for example may be defined according to Equation 1: Example of CATO cost function used for the optimisation algorithm: The cost function may include any variables and weights which may be changed at any time.

$$C = 1 \times Consumed\ Energy\ \ kWh\ - 0{,}5\ \times RegeneratedEnergy\ \ kWh\ + 4\ \times MechBrake\ Energy\ [kWh]$$

Equation 1: Example of CATO cost function used for the optimisation algorithm



LKAB iron ore trains operated in Northern Sweden,
Line Vj-Kmb (C-DAS). CATO implemented in February/March.



Tågkompaniet regional trains (S-DAS) Average/week on various lines

Figure 4: Some examples of results when introducing CATO300 based on energy consumption measured by the onboard energy meters, illustrating energy before implementation of CATO300 and the performance shortly afterwards.

A further effect brought by the CATO optimisation is shown in Figure 5; Example of how energy consumption is divided into different components. In this case, the train will gain potential energy (marked gray), which can be recovered run in the opposite direction. Energy for heating, ventilation and auxiliary power has not been included.. The bar graphs show that both the gross energy, i.e. the energy drawn from the power supply, and the net energy are reduced. It is interesting, albeit natural, to note that the optimization selects a driving profile that minimizes the use of friction brakes as well as the use of regenerative brakes. Coasting is preferred whenever possible depending on the available journey time. The decrease in gross and regenerated energy means that the catenary power load is reduced.

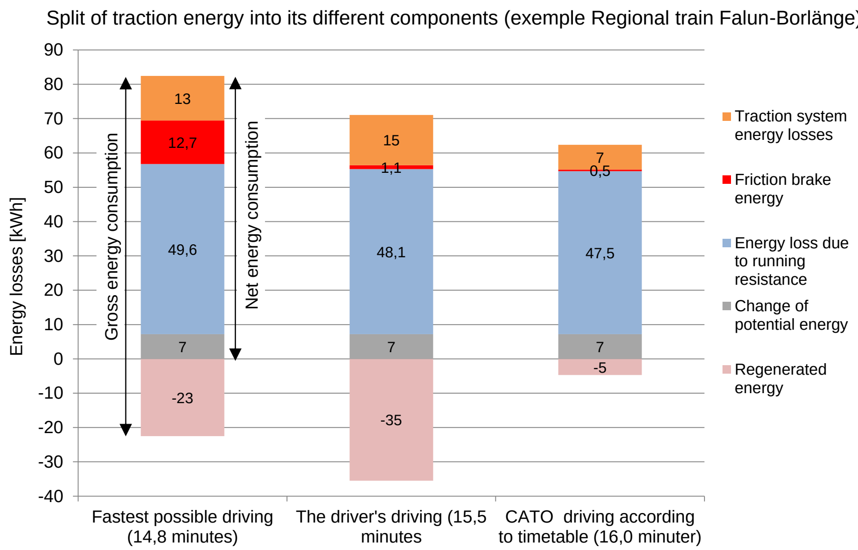


Figure 5; Example of how energy consumption is divided into different components. In this case, the train will gain potential energy (marked gray), which can be recovered run in the opposite direction. Energy for heating, ventilation and auxiliary power has not been included.

2 Connected (C-DAS) and Semi-Connected (SC-DAS) Solutions

Most DAS systems currently in operation are stand-alone (S-DAS) technologies, using the planned timetables for timing of the advice, and a strategy comparable to CATO100.

Technology like this can be deployed by the operator without the need to establish a real-time interface with the TMS, nor does it need advanced TMS functionality, but information about the actual real traffic situation, and its needs according to the real time traffic plan, is lost.

2.1 C-DAS

Connected Driver Advisory System (C-DAS) is conceptually an IM-RU system where data from defined master data sources may be changed dynamically during the journey. IM (the Infrastructure Manager) defines timing requirements, as regards schedule and adherence. RU (the Railway Undertaking) defines the economic train driving style within the limits of the timing requirements.

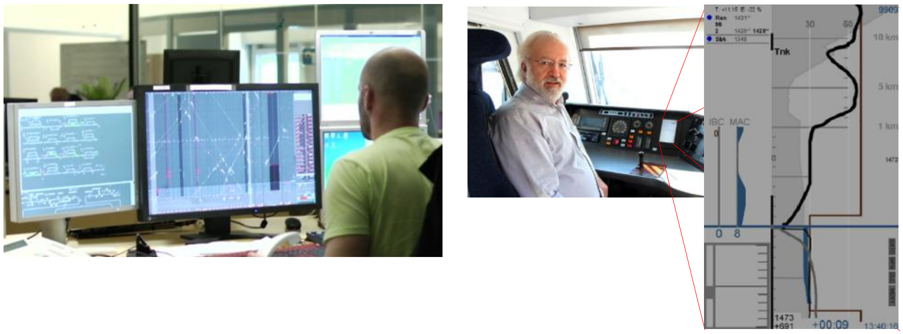


Figure 6: To the left, an example of a TMS system connected to CATO for dynamic submission of information on the real time traffic plan, route, speed restrictions, track possessions etc. To the right, the Cato Driver Machine Interface (CDMI) with advice on the optimal speed profile and information on the current schedule as well as other trains on the line..

It is obvious that C-DAS takes system optimisation a step further by providing a communications link between the DAS and the Traffic Management System (TMS). In fact C-DAS could be seen as consisting of two subsystems, a DAS and a TMS.

The TMS defines real time timing requirements with regards to scheduling and adherence to the timetable, while the DAS defines the optimum driving style within the limits of the timing requirements. Scheduling, routing and speed restriction updates are communicated to the train in real time, while information from the train enhances traffic regulation decisions at the TMS end. The TMS need to focus on steering the traffic in terms of timings and not only controlling their routes.

Simplifying the complex railway operational environment, there are three main components: rolling stock, infrastructure and operating rules (timetables). A flexible railway is simply the ability to implement ad-hoc timetable changes, as infrastructure and rolling stock are essentially fixed parameters. It is this “enabler” function of C-DAS that delivers the flexibility to change the timetable according to Traffic Management (TM) needs, i.e. enabling both ‘communication’ and ‘active correction’ to the driver. DAS is an enabler of TM as it provides the medium upon which TM decisions can be communicated to the drivers, as well as providing the channel for the increased resolution of train location and timing necessary for TM to make better decisions. Transrail has introduced the term Train Tango for the C-DAS operation connecting TMS and DAS, dispatchers and drivers. Operational flexibility by Train Tango is an enabler to efficiently solve situations of traffic disturbances and to increase traffic capacity on the railway.

Integrating driver advisory systems with traffic management systems unlocks a number of opportunities for optimizing operational efficiency, but making this connection is not without its complications. There are so far only few C-DAS systems on the market worldwide, mainly due to the current TMS products and their inability to efficiently support a DAS. Still, the advantages are obvious and these solutions will evolve. Transrail’s LKAB implementation is an early example of C-DAS.

2.2 SC-DAS

Semi-Connected DAS is conceptually a “C-DAS” but with connection only to the signaling system. This is a solution developed by Transrail for situations where legacy TMS systems cannot handle C-DAS.

SC-DAS may be used to calculate the DAS advice not only from the timetable, but also based on the motion of other trains on the line. The solution is very strong when trains are running after each other on a line. The trains can be run on a green wave with minimum headways. It is also useful if there are trains on the line, which are not fitted with a C- or SC-DAS.

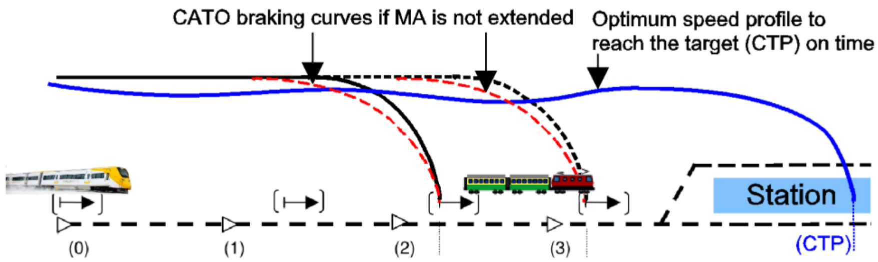


Figure 7: CATO optimal speed profile (CMP) and ATP movement authorities (MA). The optimal driving profile is calculated based on forecasts of the time when the MA will be extended due to the motion of trains ahead. The figure also explains the fundamental difference between an ATP system and DAS. ATP informs on the current status of the interlocking system (the current MAs). The DAS driving profile needs to predict the time when the MAs will be extended.

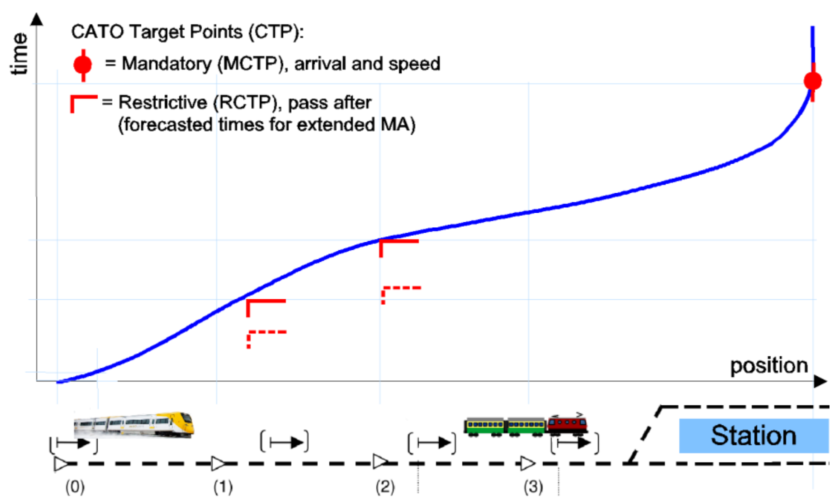


Figure 8: Situation as in Figure 7with delayed extensions of movement authorities and described in a distance-time diagram.

3 Intelligent Cruise Control (ICC) and Automatic Train Operation (ATO)

One of many aspects in the deployment of a DAS is the need to consider human factors in order to successfully harness the full potential of the technology. DAS is only a tool, so the drivers need to be able to use it correctly to get the desired results. A good C-DAS system relies on the driver's ability to read and respond to the advice it generates. An example of an early CATO Driver Machine Interface is shown in Figure 6. The CATO solution has proved that drivers can easily drive very heavy trains within seconds according to the traffic plan and even on difficult line profiles.

The intricacies of DMI design will become less important as C-DAS technologies move towards the integration of cruise functionality and ATO.

3.1 Intelligent Cruise Control (ICC), CATO Cruise

Many locomotives and multiple units of today have constant speed cruise control, very similar to what is available on ordinary cars. The next step is to use C- and SC-DAS to make the cruise intelligent. The driver presses a button and the train moves forwards in accordance with the CATO algorithm. Intelligent cruise is going to be a big thing for operators and rolling stock suppliers and it will be really popular with drivers. All the merits of C-DAS can be incorporated in the ICC.

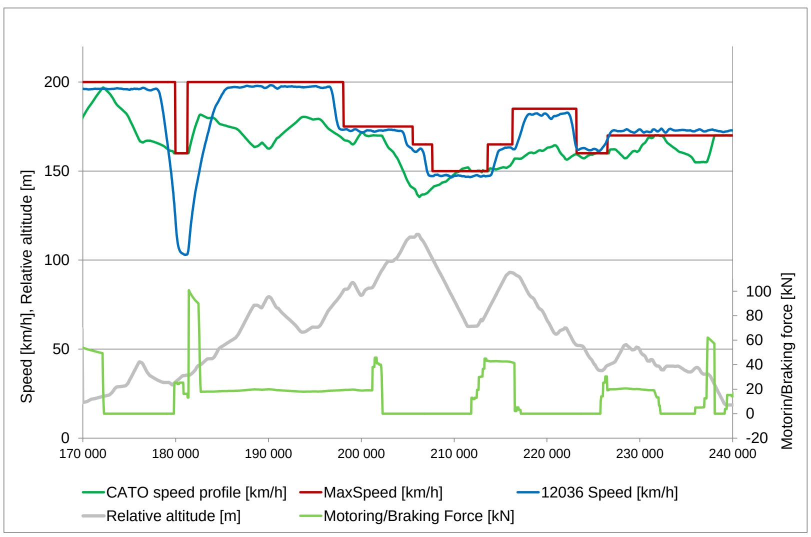


Figure 9; Example of CATO speed profile compared to a typical train run using conventional constant speed cruise control. 12036 speed is the conventional constant cruise speed control used by the driver.

It is not yet demonstrated, but we are confident that the CATO solution can efficiently drive any train from one stop to the next, from one platform to the next, and this can be done with a performance that will surpass what most drivers can achieve with a DAS.

3.2 Automatic Train Operation (ATO)

In the long perspective, ICC will lead to efficient ATO (Automatic Train Operation). CATO Cruise can be used already today as GOA2 ATO for the line haul.

Many studies have been done on ATO but often the algorithms that govern traction and braking are rudimentary, so energy usage can actually go up in ATO mode. What DAS and CATO has done so far is to enrich the technology with solutions for optimised driving profiles. ATO will always need intelligent algorithms on the train that can optimise conditions with dynamic data.

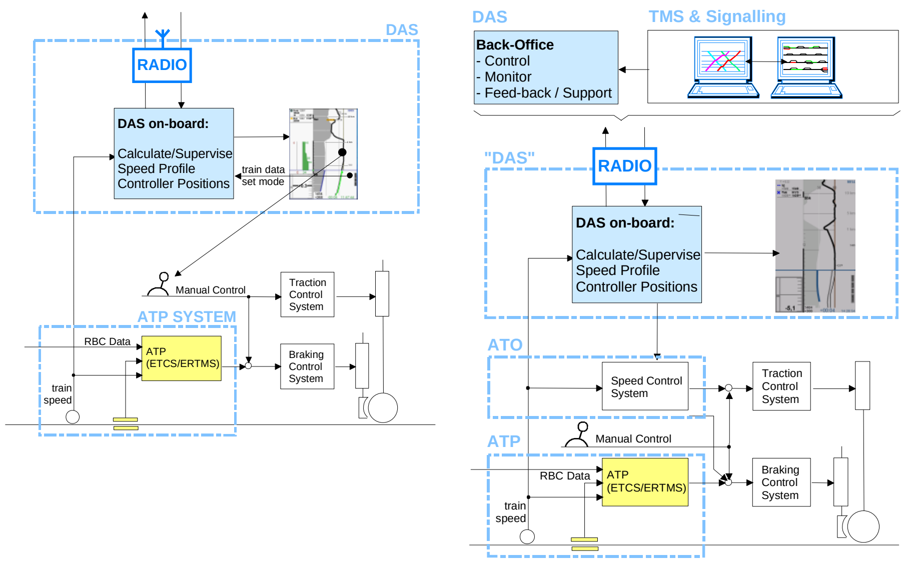


Figure 10; To the left, the general on-board architecture of DAS and ATP systems. Manual driving. To the right, the principle system architecture for an ICC or an ATO system using CATO as the "ATO engine".