Paper: Connected Driver Advisory System (C-DAS) Strategy Paper (Issue 2)

Date: 06 April 2022

From: Karl Watts, Group President, Rail Operations UK

To: Various

1. Introduction

C-DAS is a piece of technology which delivers significant benefits. These include:

- better train regulation to optimise network capacity and performance
- improved recovery from disruption
- improved support for conflict resolution (based on predicted running of trains),
- reductions in energy use and carbon emissions
- reductions in wear and tear, e.g. wheelsets and brake equipment.

Its concept has been around for over 10 years. Comprehensive detail of C-DAS is contained in an industry document entitled *'Concept of Operations for a Connected Driver Advisory System (C-DAS)'*

The document can be downloaded from the RDG website at …

https://www.raildeliverygroup.com/about-us/publications/12556-rdg-conops-nti-001-concept-of-operations-c-das-v1/file.html


Rail Delivery Group on behalf of Digital Railway

Concept of Operations for a Connected Driver Advisory System (C-DAS)

Prepared by:
Andrew Graham
Digital Railway Operations Support, Rail Delivery Group
Date: 23/8/17

Approved by:
Paul Titterton
Digital Railway Operations Specialist, Rail Delivery Group
Date: 23/08/2017.

Approved by:
Paul Sutherland
Head of Operations and Maintenance, Digital Railway
Date: 23/08/2017.

Approved by:
Andrew Simmons
Chief Systems Engineer, Digital Railway
Date: 23/08/2017

Authorised by:
Stephen Ball-Wood
Head of Engineering Projects, First Group,
Chair of Digital Railway Steering Group
Date: 25/08/2017

Working together for a better railway:

Department for Transport | Rail Delivery Group | NetworkRail | RFG Rail Freight Group | Rail Supply Group | Railway Industry Association | RSSB

Whilst there have been numerous trials of C-DAS across the network, comprehensive application of the system has never materialised. However, circumstances have changed recently and suggest that network-wide introduction of C-DAS would address a number of existing and newly emerging challenges. These include the need to:

- significantly reduce industry operating costs as a consequence of a reduction in passenger revenue
- reduce industry carbon emissions
- reduce UK transport carbon emissions through modal shift
- improve air quality through reduced particulate emissions including NoX and Sox.

As an example, traction energy alone costs the rail industry £1.1bn per annum (2019-2020 data). 88% of this cost has transferred from the former privatised passenger sector to the Treasury.

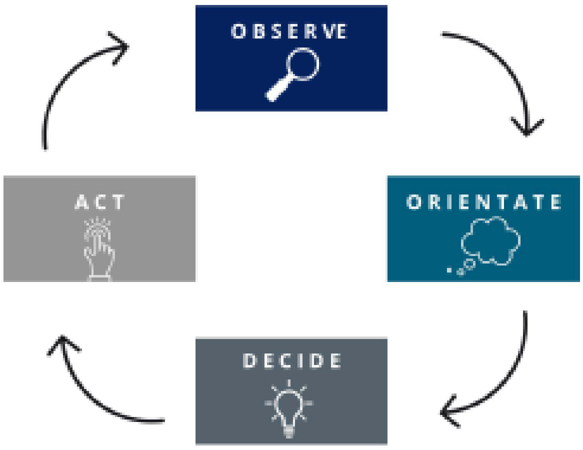
A trial of C-DAS in 2014 at Airport Junction, 10 miles west of Paddington, revealed that there was a 36% improvement in energy efficiency.

If C-DAS was introduced across the network and only improved energy efficiency by, say, 20%, this would equate to a saving of £221m per annum for the industry (at 2021 prices)**.**

The purpose of this paper is to raise awareness of the benefits of C-DAS especially in light of recent economic, environmental and social changes. The benefits of C-DAS should now be reconsidered by industry and placed on the agenda of relevant industry forums and platforms.

2. The role of C-DAS in Reducing Energy Consumption

The way in which a train is driven, in particularly, driving style, is a direct consequence of the information a driver receives, how this information is then interpreted, and finally the decisions made from information interpretation. For a train driver, this sequence of events continually repeats to form a 'loop! It can be aligned to a model derived from the US air force named the 'OODA' loop ... see graphic right....



In addition to the information received, a driver will continually consider three key influences, namely...

1) the need to continually manage safety risk
2) the need to ensure the train's schedule is maintained
3) the need to drive economically.

The consideration of these key influences allied to the information received, has a huge impact on the way in which a train is driven. The depth and quality of this information can also have a huge impact.

Unlike driving a road vehicle in which both the information received and the subsequent actions of the driver are immediate, a train driver needs to 'think ahead' in preparation for known or anticipated events, e. g. a station stop.

'Known' events, such as a station stop or a significant reduction in speed, allows the driver to prepare in advance and take the appropriate action, e.g. the suspension of traction power to allow a period of coasting prior to applying the automatic air brake. The further ahead a driver can suspend traction power and the longer a train is allowed to coast, the greater the level of energy conservation. The faster and heavier a train is, the further it is able to coast due to its high levels of kinetic energy … a product of MV^2. This can be well in excess of 10 miles in some cases.

Speed is of the essence to a driver, principally driven by the need to maintain a tight schedule. The driver will always want to arrive on time… early if possible.

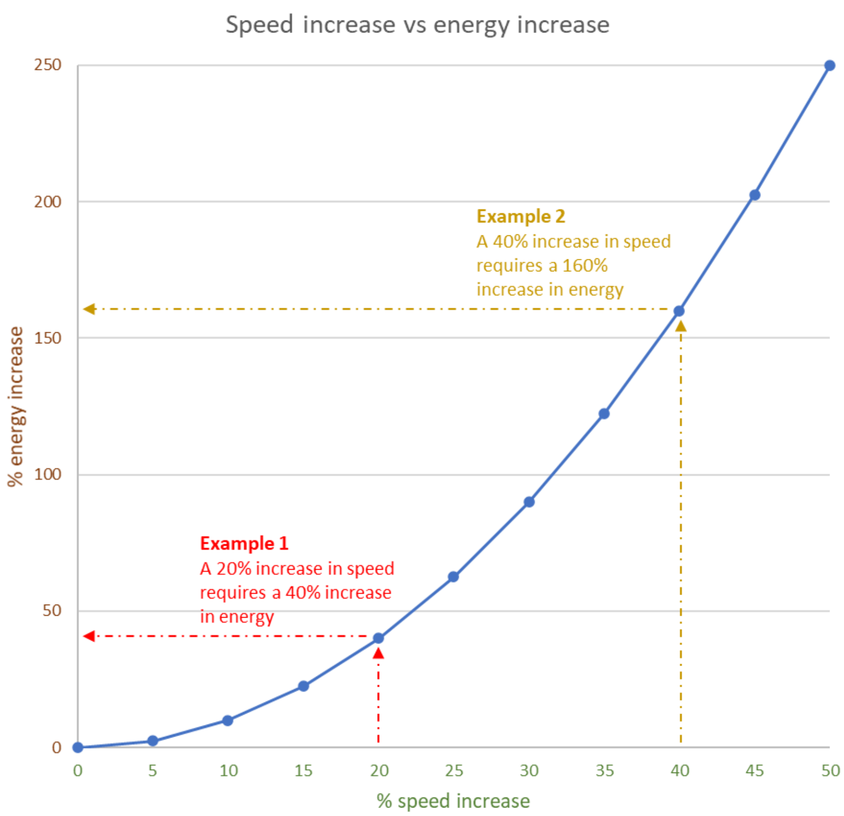
In terms of maintaining a tight schedule, this approach is fine but it conflicts with the need to preserve energy. All too often, a train is brought to a stand at the signal in the rear of the station and is held there for several minutes awaiting a vacant platform. If only the driver knew that was going to happen, he could have suspended traction power 5 miles earlier and allowed a much longer period of coasting. How much energy would that have saved? Station stops are just one example of where the driver could have saved energy, if only they'd known the detail of emerging circumstances.

If only the driver could 'see into the future'. Being able to do this would have a significant impact on how the train is driven. Every time the driver applies the automatic air brake, valuable kinetic energy is either wasted either through friction braking or partially converted into another form of energy, e.g. through regenerative braking. If only the driver knew that the train ahead (2A36) was running six minutes late and the next signal, hidden from view at the moment because it's positioned on a left-hand curve, is displaying a cautionary aspect.

When the driver finally sees the signal, unexpectedly displaying a cautionary aspect, a heavy brake application is going to be needed to reduce the train's speed from, say, 125 mph. If only the driver knew that 2A36 was running late, he could have suspended traction power ten miles earlier and allowed a significant period of coasting. Again, how much energy would that have saved?

Events like this happen continuously across the network every moment of every day. Huge amounts of energy is wasted. This adds huge unnecessary cost to the industry.

However, the most significant impact on energy comes from train speed. It is well understood that an increase in speed requires an increase in energy. This is because air resistance (drag) increases with the square of speed, and therefore the power needed to push an object through air increases with the cube of the velocity. Therefore, this increase in energy is not proportional, it's exponential. In simple terms, in order to increase a vehicles speed by just 50% will require 2½ times the amount of energy. In order to double the speed of a vehicle, requires 4 times the energy. As an example, when the speed of a car is increased from 30mph to 60mph, four times the amount of fuel is used.

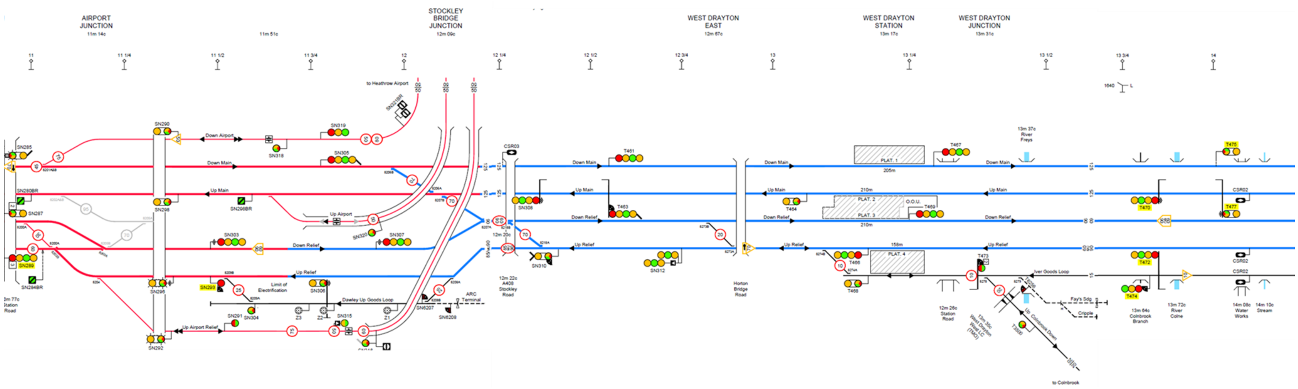


The same applies to trains. Given the large volumes of energy used by trains, even a small increase in train speed will require a significant increase in the amount of energy … and therefore, additional cost. The graph (right) illustrates the exponential profile of increased energy in relation to the increase in speed.

The reciprocal applies of course. Just a 15% reduction in train speed will use 23% less energy. In terms of the Airport Junction (image captured below) trial, in order to achieve the 36% reduction in energy, this would have required Paddington bound high speed trains to approach Airport Junction at just over 100mph as opposed to 125mph.

Ironically, the trial also revealed that arrival times into Paddington improved by an average of 90 seconds as a result of the slower approach to Airport Junction! So, how does that work? Approaching Airport Junction at 125mph only to find a signal displaying a preliminary caution (2 yellows) aspect, would require the driver to make a significant automatic air brake application and reduce speed quite considerably.

When the driver finally receives a less restrictive signal aspect, the speed of the train would then never recover enough to make up the time lost as a consequence of a severe reduction in speed. It is far more advantageous to slightly reduce the train speed in advance of the restrictive signal aspect(s) and maintain a relatively high speed, than to have to significantly reduce the train speed to such an extent that normal operating speed then becomes impossible to reattain.



Just by slowing trains down marginally to improve train ‘flighting’, especially at busy converging junctions, will have significant energy saving benefits.

Furthermore, there is a direct correlation between energy consumed and carbon emissions. By reducing traction energy consumption, not only will the industry witness significant cost reductions, industry carbon emissions will also reduce.

The advantages therefore are:

- significant reduction in energy costs
- significant reduction in carbon emissions
- improved punctuality
- reduced operating costs due to extended component life
- improved air quality.

Additionally, the system continues to improve through the provision of an inbuilt feedback loop. Not only does this continually improve the system’s efficiency but the data can also be fed into the timetabling and overall train planning processes to optimise network capacity.

3. C-DAS and Traffic Management

There is a misconception that the data inputs C-DAS requires to provide meaningful information to the driver, can only be derived from a Traffic Management system. Multiple data feeds are now available which contain a wealth of train running information.

Such data streams can be combined with other inputs to provide C-DAS with all the information it needs to provide meaningful information to the driver. This is already being demonstrated by the C-DAS system that has been designed by KeTech … https://www.ketech.com/products-services/cdas-2/

Train drivers can play a huge part in reducing traction energy consumption. However, they need to be able to 'see into the future'. C-DAS provides this capability.

If the information the driver processes in order to drive the train more efficiently is more informative and can advise of opportunities to coast or reduce speed, then significant energy savings can be made. C-DAS is the only means by which this can be achieved.

4. What Does C-DAS Mean for Freight?

The large-scale benefit of C-DAS in a freight application matches that of passenger. Whilst there isn't the same volume of freight services in the UK as there is of passenger, the amount of energy required to move a heavy freight train is significantly higher.

Furthermore, given the amount of kinetic energy captured in a heavy freight service travelling at, say, 60mph and the opportunity for long periods of coasting this presents, C-DAS can play a vital role in exploiting this opportunity.

Freight trains rely on friction braking. Freight locomotives and freight wagons are equipped with friction brakes only. Each and every time the automatic air brake is applied by the driver, valuable kinetic energy is converted to heat through friction in the brake equipment and lost to the atmosphere. There is no form of kinetic energy recovery.

The fewer times the driver applies the automatic air brake, the more energy is saved. C-DAS can inform the driver of the freight train to, for example, maintain a lower speed due to congestion several miles ahead, thus negating the need for high levels of energy consumption and subsequent heavy braking when the driver, unexpectedly, encounters restrictive signal aspects.

The vast majority of freight services use diesel powered traction. Therefore, not only would C-DAS reduce energy consumption and carbon emissions, there would also be air quality improvements through a reduction in particulate emissions, including, Nox and Sox.

5. What Does C-DAS Mean for the Class 93 Locomotive

The new Stadler class 93 locomotive ordered by Rail Operations UK, comes armed with 3 traction power sources. These are:

- 25kV AC overhead power
- 900kW diesel alternator set
- 400 kw lithium titanate oxide (LTO) traction battery set.

The diesel alternator and battery set can be utilised together giving four modes of power in total. Furthermore, the class 93 is equipped with two kinetic energy recovery systems:

- regenerative braking
- battery recharging.

Regenerative braking converts kinetic energy to electrical energy under braking. This electrical energy is then fed back into the overhead line equipment (OLE) to be reused by other electrically powered trains.

Whilst the LTO battery set can provide additional power in support of the diesel alternator set, the battery can be recharged under braking, e.g. kinetic energy is converted into electrical energy to recharge the battery in preparation for re-use when required.

Finally, the locomotive is equipped with energy metering. This equipment monitors both the electrical energy taken from the OLE by the locomotive and also the electrical energy returned to the OLE under regenerative braking. The benefit to the locomotive operator is that the payment made to the energy supplier, Network Rail, is the net of energy used and energy returned.

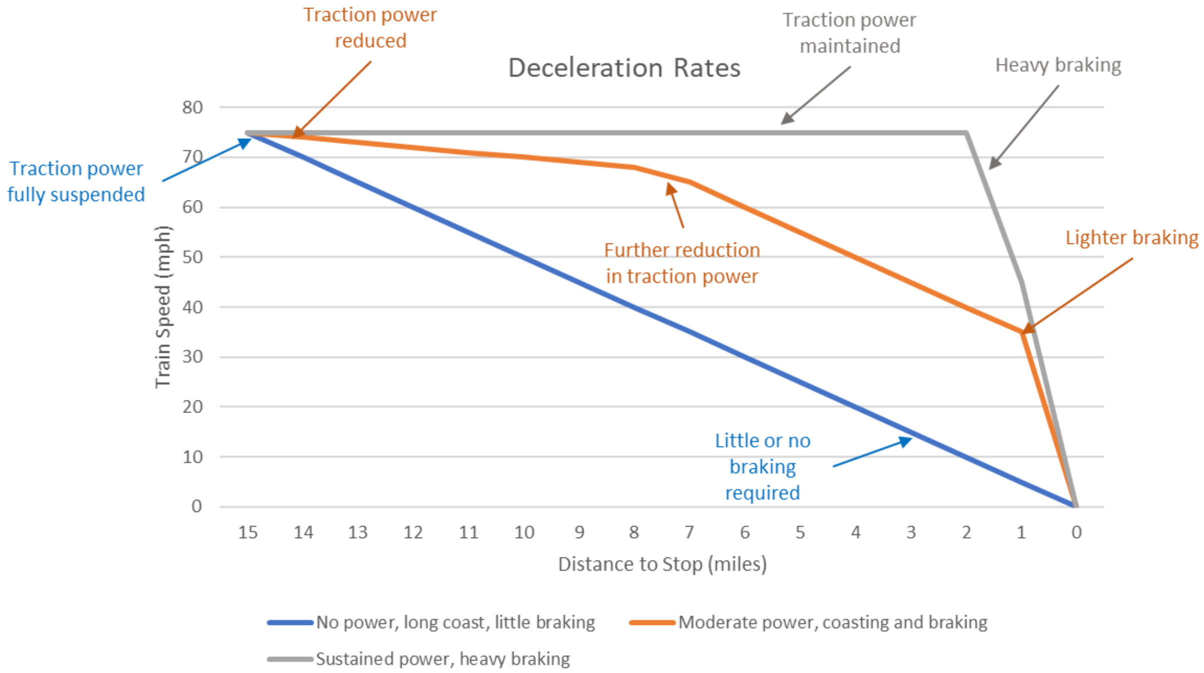
The LTO batteries have numerous operating advantages (not covered in this paper). However, LTO batteries are expensive and therefore it is imperative that the life of the battery is preserved as much as possible. The life of the battery is impacted by two things:

1) the number of discharge/recharge cycles
2) the level to which the battery is discharged.

So, given the technology afforded to the class 93, how can C-DAS help to exploit these technological capabilities? If a driver knows (through C-DAS or otherwise) that the 75 mph, 1,500 ton freight train they are driving must be brought to a stand in 15 miles or so, they have a range of approaches available to them which will determine their driving technique. These approaches are:

1) sustained power, heavy braking
2) moderate power, coasting and braking
3) no power, long coast, little braking.

The graph below gives a graphical representation of the different speed profiles these 3 examples deliver:



Even with regenerative braking, it is believed that approach number 3 will be the most energy efficient. The downside to this is the time taken to traverse the 15-mile section and the negative impact this may have on other services in the area. But it is for C-DAS to calculate the impact, make the most appropriate decision and deliver this to the driver.

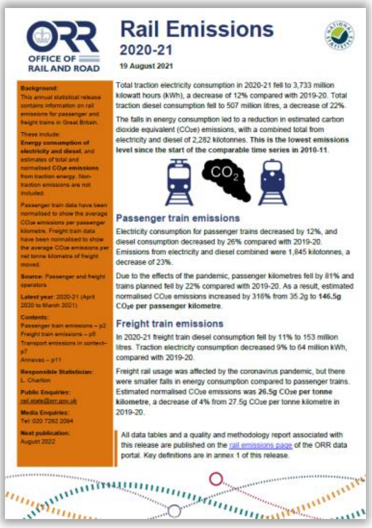
On a busy railway where every single minute of running time of every service is of critical importance, C-DAS will ultimately prioritise train regulation over energy efficiency. However, for the vast majority of the network, there will be significant energy efficiency benefits. The real benefit of C-DAS for the class 93 will therefore be reflected in energy metering. C-DAS will enable the driver to minimise energy usage thereby reducing the cost of loco/train operation.

A secondary benefit will be the conservation of battery charge. The critical thing here is for C-DAS to only allow the driver to draw energy from the battery when absolutely necessary. It is imperative that the driver does not discharge the battery unnecessarily only to find that when the battery is required, e. g. to ascend a steep rising gradient, the battery has very little energy remaining. C-DAS can prevent this.

LTO traction batteries are expensive, circa £150k per locomotive. It is imperative therefore that battery life span is protected. Battery life is negatively impacted by the number of discharge and recharge cycles. It is important therefore that the number of cycles is kept to a minimum. C- DAS can help minimise this by advising the driver of the need to use the batteries only when absolutely necessary.

6. What Does C-DAS mean for Industry Decarbonisation?

Reducing industry traction energy consumption has many advantages. Firstly, cost. Traction energy is a huge cost for the industry, circa £1.1bn (2019-2020 data). It should be noted that this cost fell to £0.925bn in 2020-2021 but this was due to the impact of Covid. 88% of this cost is for passenger train energy, a cost now borne by the DfT/Treasury as opposed to the former privatised passenger franchises.



ORR OFFICE OF RAIL AND ROAD

Rail Emissions
2020-21
19 August 2021

Background: This annual statistical release contains information on rail emissions for passenger and freight trains in Great Britain.

These include: **Energy consumption of electricity and diesel**, and estimates of total and normalised CO_2e **emissions** from traction energy. Non-traction emissions are not included.

Passenger train data have been normalised to show the average CO_2e emissions per passenger kilometre. Freight train data have been normalised to show the average CO_2e emissions per net tonne kilometre of freight moved.

Source: Passenger and freight operators

Latest year: 2020-21 (April 2020 to March 2021)

Contents:
Passenger train emissions – p2
Freight train emissions – p5
Transport emissions in context – p7
Annexes – p11

Responsible Statistician: L. Charlton

Public Enquiries: rail.stats@orr.gov.uk

Media Enquiries: Tel: 020 7282 2094

Next publication: August 2022

Total traction electricity consumption in 2020-21 fell to 3,733 million kilowatt hours (kWh), a decrease of 12% compared with 2019-20. Total traction diesel consumption fell to 507 million litres, a decrease of 22%.

The falls in energy consumption led to a reduction in estimated carbon dioxide equivalent (CO_2e) emissions, with a combined total from electricity and diesel of 2,282 kilotonnes. **This is the lowest emissions level since the start of the comparable time series in 2010-11.**

Passenger train emissions

Electricity consumption for passenger trains decreased by 12%, and diesel consumption decreased by 26% compared with 2019-20. Emissions from electricity and diesel combined were 1,845 kilotonnes, a decrease of 23%.

Due to the effects of the pandemic, passenger kilometres fell by 81% and trains planned fell by 22% compared with 2019-20. As a result, estimated normalised CO_2e emissions increased by 316% from 35.2g to **146.5g CO_2e per passenger kilometre**.

Freight train emissions

In 2020-21 freight train diesel consumption fell by 11% to 153 million litres. Traction electricity consumption decreased 9% to 64 million kWh, compared with 2019-20.

Freight rail usage was affected by the coronavirus pandemic, but there were smaller falls in energy consumption compared to passenger trains. Estimated normalised CO_2e emissions was **26.5g CO_2e per tonne kilometre**, a decrease of 4% from 27.5g CO_2e per tonne kilometre in 2019-20.

All data tables and a quality and methodology report associated with this release are published on the rail emissions page of the ORR data portal. Key definitions are in annex 1 of this release.

https://dataportal.orr.gov.uk/media/1993/rail-emissions-2020-21.pdf

The reduction in energy consumption and therefore cost was, in part, due to a reduction in services. However, an unquantifiable amount will be as a consequence of fewer delays due to less conflicting movements, e.g. drivers encountered less restrictive signal aspects.

Calculation table…

2019-2020	Diesel (litres)	Electricity (kwh)
Passenger	476,000,000	4,189,000,000
Freight	172,000,000	70,000,000
Total	**648,000,000**	**4,259,000,000**
Price per litre (£)	0.72	
Price per kwh (£)		0.15
Total cost (£)	£466,560,000	£638,850,000
Grand total (£)		**£1,105,410,000**
Cost saving	20%	£221,082,000

2020-2021	Diesel (litres)	Electricity (kwh)
Passenger	354,000,000	3,669,000,000
Freight	153,000,000	64,000,000
Total	**507,000,000**	**3,733,000,000**
Price per litre (£)	0.72	
Price per kwh (£)		0.15
Total cost (£)	£365,040,000	£559,950,000
Grand total (£)		**£924,990,000**
Cost saving	20%	£184,998,000

Kwh price includes climate change levy (CCL).

If C-DAS can return just a 20% saving in energy costs, that amounts to £221m saving per annum (assuming a return to full timetable operation).

In terms of traction decarbonisation, there is a direct correlation between energy consumption and carbon emissions. If energy consumption is reduced, carbon emissions are reduced. If we can reduce our energy consumption by 20%, we can reduce or carbon emissions by 20%.

Associated with energy reduction is cleaner air. We will witness a reduction in Nox, Sox and other particulate emissions.

Finally, with less diesel engines returning to full power each and every time a train is unexpectedly stepped or severely speed checked, noise emissions are also reduced.

7. Conclusion

C-DAS, as a nationally rolled out system, can deliver huge economic social and environmental benefits for the UK rail industry. However, the value lies in choosing a system that can provide the benefits of ETCS before it is rolled out and will integrate seamlessly when it is; closing the gaps that will still exist on the network upon completion. The C-DAS that will deliver the most benefits to the industry, is a system that has the capability to grow with the industry as it embarks on its journey towards digital transformation.

C-DAS must now be viewed as an **industry system** tool for delivering cost reductions, carbon reductions and other social benefits.

The rail industry, through system collaboration, must revisit the introduction of C-DAS but, this time, in the context of it being an industry wide system tool which can deliver the benefits listed above.

Karl Watts
Group President

Rail Operations (UK) Limited
Orion high speed logistics

+44 (0)7793 767218
karl.watts@railopsgroup.co.uk
Second Floor,
Wyvern House,
Railway Terrace,
Derby DE1 2RU

KeTech Better Informed Journeys

0330 057 8450
info@KeTech.com
3 Fulwood Park,
Caxton Rd,
Fulwood,
Preston PR2 9NZ

www.railopsgroup.co.uk orion.railopsgroup.co.uk

www.KeTech.com