Institution: University of Bath

Unit of Assessment:12: Aeronautical, Mechanical, Chemical and Manufacturing Engineering

Title of case study: Helping to create Ashwoods Lightfoot® and enable fleet managers to reduce the fuel costs and CO_2 footprint from 2,500 vehicles

1. Summary of the impact

Economic impact

- Design of a new and award winning product called Lightfoot® that gives reductions of at least 10% in fuel use and CO_2 emissions.
- The creation of a new business, Ashwoods Lightfoot® and three new jobs, with a sales value to date in excess of £625,000 and a subscription base of over £10,000 per month.
- Economic performance of 200 vehicle fleets, including six major operators, has been improved by 2,500 installations of the system, saving over £83,000 per month in fuel costs.

Environmental impact

- Saving an estimated 2,000 tonnes of CO_2 per year.

2. Underpinning research

Key researchers

Members of the Powertrain and Vehicle Research Centre (PVRC): Professor CR Burrows (Professor since 1987, emeritus since 2007); Dr ND Vaughan (Senior Lecturer 1993-2002); Dr CJ Brace (Research Officer 1992-2000, Lecturer 2000-2006, Senior Lecturer 2006-2012, Reader since 2012); and Mr R Daniel (Masters Student 2007)

Research at Bath to understand driver behaviour began during a DTI project in collaboration with Ford, Lucas Diesel Systems and Johnson Matthey (1992-1996). The project exploited the capability of a diesel engine, coupled with a continuously variable transmission, to operate the engine at its most efficient level at all times. It was found that the strategy of optimising only for fuel efficiency led to low driver acceptance, with the driver finding the vehicle unresponsive. This was a major barrier to adoption, which motivated further research at Bathin this field [1].

This led to an EPSRC funded research programme in collaboration with Ford and Torotrak (GR/K99664/01, 1996-2000), using the insight gained during the initial DTI project to improve driver acceptance. An extensive series of fundamental experiments were performed to understand and quantify driver perception during a wide range of simulated vehicle acceleration scenarios.

An important conceptual parameter in this work was driver aggression, which is a measure of the driver demand and the vehicle's ability to respond. The resulting data allowed the formulation of models to describe the driver's perception of vehicle behaviour. These models provided a means of predicting driver response to novel engine control strategies, for the first time defining a relationship between driver aggression and fuel consumption [3]. This advance meant that vehicle driveability could be included in the optimisation process, allowing the trade-off between driveability and fuel consumption to be addressed during the simulation phases of a vehicle development programme. This reduced the duration and cost of the entire development process by reducing the number of iterations required [2].

Research in this area was extended through driving experiments that demonstrated that for some specific road conditions, for example, stop-start urban traffic and ring roads with high permitted speeds and many traffic islands, the most aggressive drivers use up to 50% more fuel than the least aggressive [4]. This surprising finding has significant implications for both traffic planners and for vehicle designers. Further research in partnership with Mahle Powertrain applied the techniques developed by the Bath team to understand the impact of real-world driving behaviour on the accuracy of engine diagnostic algorithms. This resulted in the development of an algorithm (Universal Driver Aggression Algorithm or UDAA) to measure driver aggression [5]. An important aspect of the UDAA is its inherent robustness across differing vehicle types and road configurations. The UDAA offers a step change in vehicle management technology as it is directly applicable across a wide range of situations with minimal requirement for labour intensive fine tuning. The UDAA subsequently inspired activity within a project in collaboration with Ashwoods Automotive as described below.

3. References to the research (* references that best indicate quality)

1*. M Deacon, CJ Brace, ND Vaughan, CR Burrows and RW Horrocks RW. Impact of alternative controller strategies on emissions from a diesel CVT powertrain, 1999, Proceedings IMechE, Part D, Journal of Automobile Engineering, **213**, 95-107. DOI: 10.1243/0954407991526711

2*. V Wicke, CJ Brace and ND Vaughan. The potential for simulation of driveability of CVT vehicles, 2000, Transactions of the SAE, Journal of Passenger Cars - Mechanical Systems, **109**, Paper 00PC-218 (6 pages). DOI: 10.4271/2000-01-0830

3*. SG Pickering and CJ Brace. Automated data processing and metric generation for driveability analysis, 2007, Proceedings IMechE, Part D, Journal of Automobile Engineering, **221**, 429-441. DOI: 10.1243/09544070JAUTO347

4. S Malek, CJ Brace and S Liu S. Effect of driving behaviour on fuel consumption, 5th International Conference on Driver Behaviour and Training, 29-30 November 2011, Paris 375-82. ISBN: 9781409443049

5. R Daniel, T Brooks and D Pates. Analysis of US and EU drive styles to improve understanding of market usage and the effects on OBD monitor IUMPR, 2009, SAE Technical Paper 2009-01-0236. DOI: 10.4271/2009-01-0236

4. Details of the impact

In 2009, a Knowledge Transfer Account (KTA) funded project between Bath and Ashwoods Automotive, an Exeter based SME, was focused on the optimisation of hybrid electric powertrains. It became clear that realistic driver behaviour had a far more significant effect on CO_2 production and fuel efficiency than that possible through design improvements, as is the case in conventional vehicles.

Because of the importance of driver behaviour for all types of vehicles, and following discussions between Bath and Ashwoods based on these findings, a new product (Lightfoot®) was created by Ashwoods that incorporated the Universal Driver Aggression Algorithm (or UDAA) which arose from the Bath research [5]. The development of this product relied heavily on the Bath team to ensure that the full benefits of the research findings could be realised. Ashwoods engineers were seconded to Bath during the product development, ensuring effective knowledge exchange and exploitation of the research.

Lightfoot® was launched in 2011 through a new business venture, Ashwoods Lightfoot, which owns the IP relating to the product, creating three new jobs. The product is marketed to fleet operators of light commercial vehicles. The system consists of a data processing module and a driver display system that can be integrated into the existing dashboard instrumentation and is connected over the mobile phone network to Ashwoods' central servers. The system makes use of data readily available from the vehicle's diagnostic computer. The data are processed using the UDAA algorithm developed in the underpinning research both to quantify driver aggression and to optimise gear shift strategy. This approach allows Lightfoot® to be fundamentally more effective than competing products, which simply aim to indicate to the driver when to change gear, due to its ability to modify driver behaviour in a robust and universally applicable manner. This represents an important strategic advantage to Lightfoot®, significantly improving driver acceptance and minimising the application support needed for each new fleet user.

Lightfoot® uses visual and audible feedback to drivers to help them improve the fuel efficiency of their driving. In addition, the system reports back to the fleet manager who oversees a ranking and monitoring system to reward the best drivers and encourage those who need to improve. The reduction in CO_2 emissions is achieved solely through behavioural improvements, with no modification to the vehicle engine.

During the development phase, trials run on customer fleets by Ashwoods demonstrated that Lightfoot® saved an average of around 7% in fuel/CO_2 when compared with baseline measurements across a wide range of drivers and duty cycles. The savings were even higher for exceptionally aggressive drivers and highly dynamic duty cycles; in these cases savings of up to 20% were achieved [A, B]. In service, the product has consistently returned a saving of at least 10% [C].

Lightfoot® has been a commercial success and is the sector leading product, winning a number of industry awards [D]. The work undertaken by Bath, exploiting the underpinning research has been central to this success. In the words of the Ashwoods Managing Director [C]:

> '*The innovative work of the PVRC has contributed directly to our business. The novel driver aggression monitoring algorithms developed with the University have helped our Lightfoot product to become the leading offering of its class.*'

The impact here is immediate and persistent. The beneficiaries are Ashwoods Automotive, through increased sales (value of the 2,500 unit sales to date are around £625,000) and a rising profile within a new product sector [C].

In addition, the six major fleet operators that use the technology have gained significant reductions in fuel costs, valued at over £83,000 per month on the current number of installations. Over 50 subsequent trials have now been run by large fleet operators with savings ranging from 8 to 23%. Northumberland County Council saved 13.5%, Coventry City council 12.7%, DAF 9.9%, and May Gurney 14.3%. User experience has been positive, for example, Wiltshire County Council [E] states:

> '*We have improved our consumption by 8-10% on these vehicles. The system is easy to manage, relies on the driver to drive correctly to make the savings, and therefore does not take up officer time. As the potential savings are significant, it is our intention to invest in Lightfoot in the future.*'

The largest user is Autoglass, which has adopted Lightfoot® across its entire fleet and has seen rapid and significant improvements. In the words of the Autoglass Managing Director [F]:

> '*Within a couple of days of using the tool we see many of our drivers go from spending 55—60% of their time in the green zone to hitting 90% and higher. Our savings in fuel costs speak for themselves. …*
>
> *… Our technicians have really embraced the technology…We've even seen some light-hearted competitiveness emerging when the manager reports go up on the notice board every week.*'

Fleet operators spend around 25% of their cash flow on fuel, so any saving in this area can be passed on to the general public through a reduced price of goods and services. The wider environment benefits through reduced CO_2 from the vehicle fleet are clear. The annual impact of the 2,500 currently operational systems can be estimated by considering the effect of a 10% saving relative to the current fleet average CO_2 emissions from light commercial vehicles, estimated in 2010 by AEA at 207.6 gCO_2/km across a fleet of 2500 vehicles travelling an average of 25,000 miles each year [G]. The saving is in over 2,000 tonnes of CO_2 per year.

Figures 1 and 2 show actual changes in driver accelerator pedal activity before (Baseline) and after (Live) activation of Lightfoot®. These changes, represented as probability density distributions, give rise to the savings determined in [G].

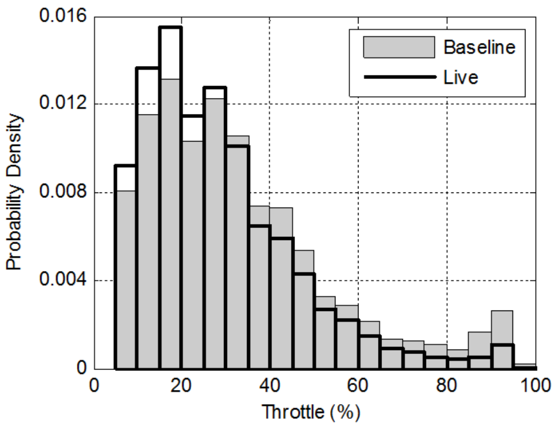

Fig. 1: Accelerator pedal (throttle) activation probability density before (Baseline) and after Lightfoot® was activated (Live). Note the shift towards lighter pedal activation when the device is active. Fuel use is proportional to accelerator pedal position.

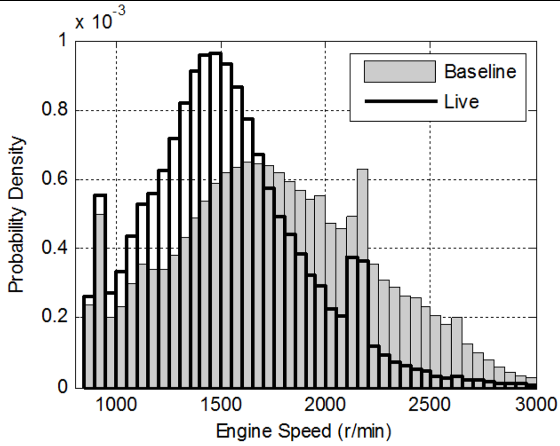

Fig. 2: Engine speed probability density before (Baseline) and after Lightfoot® was activated (Live). Note the considerable shift towards lower engine speeds when the device is active. Lower engine speeds are typically more efficient for an equivalent power output due to reduced friction.

5. Sources to corroborate the impact

A. C Vagg, CJ Brace, R Wijetunge, S Akehurst and L Ash. Development of a new methodology to assess fuel saving using gear shift indicators, 2012, Proceedings IMechE, Part D, Journal of Automobile Engineering, **226**,1630-1639. DOI: 10.1177/0954407012447761

B. C Vagg, CJ Brace, D Hari, S Akehurst, J Poxon and L Ash. Development and field trial of a driver assistance system to encourage eco-driving in light commercial vehicle fleets, 2013, IEEE Intelligent Transportation Systems Transactions, **14**, Issue 2, 796-805. DOI: 10.1109/TITS.2013.2239642

C. Corroborative statement from Lightfoot Operations Manager, Ashwoods Automotive, 30 September 2013.

D. List of awards won by Lightfoot (http://www.ashwoodslightfoot.co.uk/awards/).

E. Testimonial from Ashwoods Lightfoot Website (http://www.ashwoodslightfoot.co.uk/testimonials/).

F. J Challen. Autoglass to save 15 per cent on fuel with Lightfoot, Article published in Transport Engineer, 11 July 2013 (http://www.transportengineer.org.uk/transport-engineer-news/autoglass-to-save-15-per-cent-on-fuel-with-lightfoot/52916).

G. AEA report - Light Goods Vehicle - CO2 Emissions Study: Final report. Report Ref ED05896/TR Issue Number 2, 2010.