BASIC STEPS TO IMPROVING VEHICLE FUEL EFFICIENCY

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Introduction

Against the background of ever increasing fuel costs, principally caused by the fuel price escalator, many companies are under pressure to improve their fuel consumption. Additionally by reducing fuel consumption, companies can project a greener image. There are many interventions (products and services) which claim to improve fuel consumption but few have been subject to independent rigorous analysis. Whilst specific mathematical techniques have their supporters, mathematical techniques are of secondary importance. Of primary importance is the testing procedure. Wilcox (1998) reporting on the 1998 IRTE/BTAC trials raised the issue of 'familiarity'. Additionally, 'seasonality' and its implications for testing in an operational environment were discussed by Coyle, Murray and Whiteing (1998). Another consideration is how much of an improvement is the result of introducing an intervention and how much is the result of the driver(s) changing their behaviour? This change in behaviour may be caused by noticeable changes in the monitoring process or the drivers being aware that they are part of an experiment.

There is though a body of knowledge that has been steadily building up over many years that has proven to be effective and financially viable. It is from this body of knowledge that examples are drawn to form the core of the second and third themes in this presentation. The first theme is the basic building block - data, its management and uses. Finally it is intended to discuss some of the aspects associated with more marginal, or what some have described as more exotic, interventions.

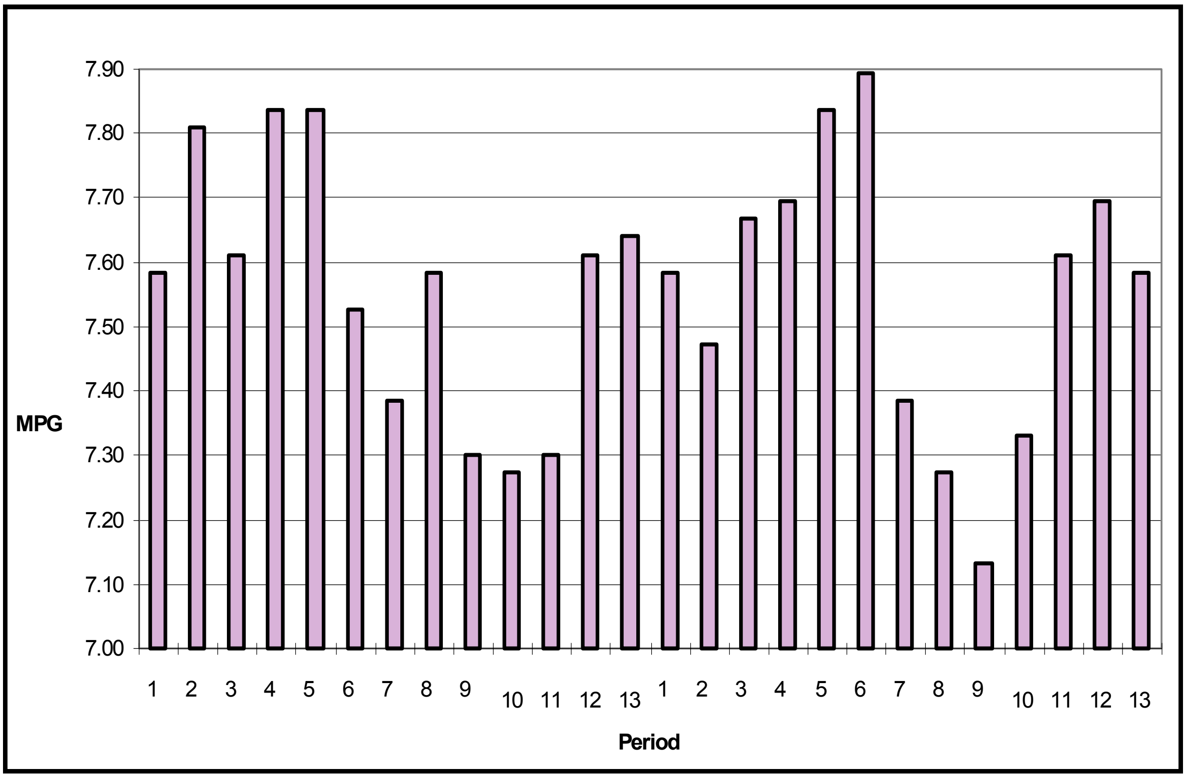
The Three Themes

1. Data
2. Making the most effective use of what you already have
3. Making the most effective purchasing decisions

Theme One

Without accurate data, the risk of making a poor decision increases. Figure 1 shows the fuel consumption pattern for a large UK fleet. This pattern has been found in other fleets whose data has been analysed. There are thirteen periods in a year, in this example, because the information comes from an accounting system. Period one, begins at the beginning of the financial year in April. A seasonal pattern is noticeable. If an intervention is introduced when mpg is rising due to seasonal influences and base line periods have been seasonally low it is possible to over emphasise the effect of the intervention. Even worse, an intervention that might not work can give the impression of being effective. If the previous year's average mpg is taken the same type of error can still be made on both the upward and downward slopes of the peak. For this reason vehicles with an intervention applied should always be compared with a control group of vehicles. Where possible drivers should be unaware that an intervention has been applied, though there are ethical and industrial relations factors that have to be considered. Also, when possible 'before ', 'after' and 'as before' tests should be conducted.

Figure 1. Seasonality in a large UK fleet.



Having obtained good quality data, in certain circumstances, financially effective decisions can be made which do not require any expenditure. Consider the following example, which has been updated to reflect the March 1999 budget increase in fuel prices. The application of effectiveness analysis (EA) undermines the argument of identical vehicles producing the same mpg and shows how once accurate data has been obtained it can be used to produce savings without spending money. The cost to the company was the time spent by a junior manager checking and where necessary filling the fuel tanks on the three units on a daily basis.

<u>An Example of Effectiveness Analysis</u>

Background

Local distribution work is undertaken by a fleet of 17 tonne and 7.5 tonne rigid vehicles. There are three 38 tonne units that undertake three overnight trunk runs and then one of these units is used during the day to take on an additional trunk run. The remaining two units are occasionally used for local delivery work.

The distances for the four routes are shown below:

- Route 1 - overnight trunk of 300 miles.

- Route 2 - overnight trunk of 350 miles.
- Route 3 - overnight trunk of 410 miles.
- Route 4 - day-time trunk of 300 miles.

The traffic department assumed that because the units were identical models, were of a similar age and the trailers were carrying similar weights they would produce the same fuel consumption. Obtaining and analysing accurate fuel consumption figures revealed that the average MPG for the three vehicles was:

- Unit 1 - 7.3 MPG
- Unit 2 - 7.15 MPG
- Unit 3 - 6.5 MPG

Note: The drivers were moved between vehicles and the vehicles between routes to ensure it was the vehicle which produced the above results.

Before applying EA to the fuel costs, unit three was used on routes one and four, unit two on route three and unit one on route two. The average daily fuel consumption is shown in Table 1.

Table 1. Daily Fuel Consumption

Unit & MPG	Route	Distance (Miles)	Fuel Used (Gallons)
1 – 7.3	2	350	47.945
2 – 7.15	3	410	57.342
3 – 6.5	1 & 4	600	92.308
Daily Fuel Usage			**197.595**

Action
By assigning the vehicles with the best fuel consumption to the longer trunk runs fuel consumption was reduced, as shown in Table 2.

Table 2 Reduced Fuel Consumption

Unit & MPG	Route	Distance (Miles)	Fuel Used (Gallons)
1 – 7.28	3 & 4	710	97.527
2 – 7.15	2	350	48.951
3 – 6.6	1	300	45.455
Daily Fuel Usage			**191.933**

Outcome
The daily fuel saving was 5.662 (197.595 - 191.933) gallons or 2.87%. At a price of £2.63 per gallon, operating five days per week for 50 weeks per year an annual saving of £3,723 is produced. Route four involved the most hill work and therefore accounted for the slight change in consumption figures when it was reallocated to unit one from unit three.

This example also shows the application of theme two, that of making the best use of your present assets.

Theme Two

Many companies still do not appreciate the benefits of driver training, yet driver training can produce quite impressive results. However, there is a caveat, the training needs to have some sort of reinforcement mechanism. This can take the form of league tables, targets, individual letters and fuel bonuses. The reinforcement mechanism needs to be carefully thought through to ensure it has a continual incentive effect.

Table 3 shows the results of a driver training programme that took place in November when the seasonal trend was showing a reduction in mpg. Despite this downward trend an improvement was made. The training was 'on the job'.

Table 3. Results of driver training.

Driver	$MPG^{(1)}$	MPG August	MPG September	MPG October	$MPG^{(2)}$	$MPG^{(3)}$	Improvement %
Artics							
1	6.59	6.72	6.49	5.92	7.98	7.78	31.42
2	6.51	6.25	6.76	6.67	6.87	6.86	02.85
3	7.04	7.52	7.00	7.23	7.56	8.18	13.14
4	6.61	8.25	6.83	5.73	7.91	7.52	31.24
Rigids							
1	7.3	6.27	6.29	6.14	8.36	7.07	15.15
2	7.27	7.93	7.13	7.45	7.69	8.14	09.26

$MPG^{(1)}$ Previous year's (January to December) MPG
$MPG^{(2)}$ MPG achieved on training day
$MPG^{(3)}$ MPG for November
Improvement % is calculated by ((November MPG - October MPG) / October MPG)

Two of the drivers (3 & 4) in this analysis both went to the same destination 217 miles away, departing at the same time. Most of the journey was via the motorway network and the departure time was 3:00 AM. The first vehicle, an F10 was speed limited to 60 mph, the second an FL10 was limited by its driver 56 mph. The difference between the arrival times at the destination was four minutes. The return journey required the vehicles to make slightly different detours but the overall distance was the same as can be seen in the Table 4. The effect on fuel consumption can also be seen. However the fact that they are two different models must be taken into consideration when comparing fuel consumption. This also took place the day that driver 4 was being trained.

Table 4. Comparison of maximum speed and fuel consumption

Driver	Max speed	Distance (KM)	Fuel used (Litres)	MPG
3 - FL10	56	718	237	8.55
4 - F10	60	718	256	7.91

At a fuel price of 58 pence per litre the saving is £11.02 in one day.

Theme Three

The Energy Efficiency Office (EEO) produced two significant guides on the use of aerodynamic aids in 1990. On closer examination, they contain some very significant facts. The first being the existence of a Pareto effect, the second which is applicable to the Argos/Exel Logistics case study, is that the reduction in drag permitted the use of a more fuel efficient final drive ratio.

Using the Pareto effect.
Table 5 examines the drag reduction data from the Argos/Exel project and from this it is possible to see that the greatest reductions in drag come from the first three components. Therefore, fitting these components only, will, assuming that a full kit was going to be purchased for a vehicle, release money for fitting the three most effective components to another vehicle. Adopting this simple approach will improve the overall fleet fuel consumption.

Table 5. Analysis of components and reductions in aerodynamic drag (Ref: EEO EPP 335)

COMPONENT	Reduction in drag coefficient Cd	Percentage reduction in Cd	Accumulated reduction in Cd	Accumulated percentage reduction in Cd
Cab roof fairing	0.192	49.10%	0.192	49.10%
Body collars and radiused body roof corners	0.082	20.97%	0.274	70.08%
Air dam	0.040	10.23%	0.314	80.31%
Body side skirts	0.035	8.95%	0.349	89.26%
Box body roof, rear taper and corner foldings	0.021	5.37%	0.370	94.63%
Cab 'A' post turning vanes	0.017	4.35%	0.387	98.98%
Wheel trims	0.004	1.02%	0.391	100.00%
Total reduction in Cd	.391	100%		

To minimise the cost and increase the payback the front air dam, should where possible, be specified when purchasing the vehicle. Additionally, specifying radiused (min 200 millimetres) leading front edges for the bodywork will reduce costs. If prioritising, then the first component fitted to the vehicles should be the cab roof fairing and then, if the budget allows, the following components in Table 5 in descending order.

When considering retrofitting of such equipment, with a limited budget, fitting cab roof deflectors to as many vehicles as possible will be the most effective use of the budget, bearing in mind the payback period and the remaining operational life of the vehicle in the company.

A cautionary note though. The EEO case studies were under operating conditions, not test track conditions at a constant 56 miles per hour. Fuel savings from aerodynamic aids are highly sensitive to speed. Therefore, it is important to establish what the average speed or expected average speed is of the vehicle to which the equipment will be fitted, and ask for test track results at that speed.

Whilst this analysis has looked closely at a rigid vehicles, operators of articulated vehicles should apply a similar analysis to EEO project profile 355 which was based upon two TNT units and four trailers.

Selecting a final drive ratio
The vast majority of vehicles have various engine and transmission options available. Generally there are three final drive ratios available. Table 6 describes the ratios and gives a simplistic explanation of the operational settings in which the ratio would be used. The mixing of engine specification, and transmission (gearbox and final drive) ratios is a science. Where a vehicle runs out of cubic capacity before reaching its designated gross weight an opportunity arises for changes to made to each of these.

Table 6. Final Drive ratio

Ratio	Operational setting
3.0 : 1	Long distance
4.0 : 1	Mixed
5.0 : 1	Urban

The difference between the ratios is not usually as large as shown in the table and the figures used are to aid the description. The long distance ratio indicates that the engine has to rotate three times to turn the road wheels once (assuming top gear is a 1:1 ratio). Whereas the mixed operations ratio requires the engine to turn four times to rotate the road wheels once. If it were possible to change from 4:1 to 3:1 there would be a reduction in engine revolutions and consequently fuel requirement of 25%. In practice though the straightforward mathematical savings are reduced by other factors. However, savings can still be made.

By reducing the Cd there is a reduction in the torque necessary to turn the road wheels so in the Argos/Exel project it was possible to move to a more fuel efficient ratio (the actual ratios being a 5.409:1 ratio originally and changed to a 4.808:1). Any organisation should consider the final drive ratio required aerodynamic aids are to be specified for new vehicles and/or trailers.

Knowledge of these ratios opens up additional opportunities to improve fuel consumption in two ways, one where vehicles are double shifted, the other where a company can break its work down into operational types or sectors.

Some of the companies involved in the Huddersfield fuel efficiency project have vehicles that are double shifted. That is, the vehicle does a long distance night trunk and a day shift which consists of local or mixed operations. Invariably these vehicles tend to be fitted with a final drive ratio suitable for mixed operating conditions. What we are considering is changing the final drive ratio to suit the long distance work. The expected outcome is that there will be an improvement in mpg for the long distance work that will more than compensate for an increase in fuel consumption on the mixed or local work. There are of course other considerations to be taken into account, such as fleet management policy, which may be to place new vehicles only on the long distance work. The vehicles previously undertaking this work are then put onto other work (mixed or local). A possible solution is to separate the work into operational sectors and adopt the fleet policy to maximise fuel efficiency for individual sectors of operation. The policy of using operational sectors can also be applied to the fitting of aerodynamic aids because as already stated the benefits are highly sensitive to speed. Therefore, vehicles that do a lot of low speed work such as operating in an urban environment will not benefit from the use of such equipment.

Having gone in great detail into what has been described as basic interventions it is only correct to mention other basic and not too expensive interventions, though in less detail.

- Fit an engine speed limiter.
- Correct specification of vehicle and trailer to reduce the gap between the front of the trailer and the back of the cab.
- Specifying body work that gives the necessary cubic capacity whilst minimising height and width.
- Monitoring maintenance reports and fuel consumption to identify rogue vehicles and drivers
- Monitor fuel stocks accurately
- Obtain an accurate mpg figure for vehicles and driver through the use of 'base of neck' to 'base of neck' refuelling.
- Develop a fuel efficiency culture for <u>all staff</u>, if feedback on mpg is to be given then indicate the reductions in emissions achieved, also tell your suppliers and customers what you are doing.
- Use spreadsheet models to indicate the fuel efficiency costs and benefits of decisions.
- When purchasing a new Large Goods Vehicle have the fourth needle on the tachograph activated to record engine revs and <u>use</u> the information
- Review maintenance procedures for example, are tyre pressures being checked when cold?
- Truck manufacturers are providing free training for drivers aimed at improving safety and fuel consumption, take advantage of it. If you operate a car or van fleet ask your supplier why they don't supply a similar service. Some truck manufacturers also make cars and vans.
- Reinforce driver training for all staff.

There are of course more expensive interventions that work if used correctly, such as on-board computers or driving aids like Road Relay or Cat ID.

Other interventions

There appears to be a constant stream of interventions that claim to improve fuel consumption, it is not intended here to highlight any particular intervention or type of intervention but rather to raise awareness of validity. A recent analysis of the United States based Environmental Protection Agency (EPA) device and additive test list (EPA420-B-98-

003) indicated that of 107 interventions on the list:

- six were considered to have "*Indicated a statistically significant improvement in fuel economy without an increase in exhaust emissions although cost effectiveness must be determined by the consumer for his particular application*".
- four interventions "*Indicated a statistically significant improvement in fuel economy but with an increase in exhaust emissions. According to Federal Regulations, installation of this device could be considered tampering*".
- one was found to "*Reduce carbon monoxide and hydrocarbons on older emission control technology vehicles*".

Most of the devices are aimed at cars with petrol engines though some can also be applied to cars with diesel engines and larger vehicles. The tests are carried out in a laboratory. The testing is voluntary unless the agency is directed to test a product by an EPA administrator or the Federal Trade Commission (FTC). **The EPA does not approve, certify, register or endorse products**. Furthermore, "The evaluation programme is restricted to fuel additives and devices and does not apply to oil additives and lubricants".

The application of appropriate statistical techniques to data from valid testing procedures can indicate that some interventions borderline as to their effectiveness. The suggested strategy here would be, provided that the interventions are not mutually exclusive, to test two or more of them on an intervention vehicle or vehicles. For example, low energy tyres, oil additive, and fuel additive all being applied to the same vehicle(s).

Conclusion

By introducing basic interventions that cost very little in terms of time, effort or money, savings can be generated which permit the introduction of more expensive interventions. The basic interventions discussed here are not an exhaustive list. Additionally, gaining experience in data collection and management will aid the development of a more fuel efficient culture. A major source of information on vehicle dynamics and their effect on fuel consumption is the IRTE/BTAC fuel trials held annually. This event is probably the best and cheapest way for a company to conduct tests under controlled conditions, in the UK.

The three themes discussed here are designed to provide vehicle operators with a simple framework from which to work. The most important and sometimes daunting step is that of collecting data and then ensuring its accuracy. The suggested strategy for large fleets is to do this at a small depot as a pilot rather than across the company fleet. This will reduce the total resource requirement and hopefully operators will learn from making mistakes only once rather than repeating them at several depots at the same time. The software required to undertake this form of analysis is no more than a spreadsheet. Indeed a spreadsheet was all that was used in the example of effectiveness analysis.

This year the T&LRU will be taking a more participative role with the operators in the research project to develop and refine the procedures and mathematical techniques for testing more marginal interventions. We look forward to keeping you informed of our progress.

References

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