A GUIDE TO TESTING FUEL SAVING INTERVENTIONS IN ROAD TRANSPORT APPLICATIONS IN ‘LIVE’ CONDITIONS USING IFSITS

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1 INTRODUCTION

Working with vehicle operators and intervention suppliers for many years to test fuel saving interventions ‘live’ in operations it became obvious that there was a need for good quality guidance for vehicle operators on how to develop a strategy and manage a ‘live’ test. This guide aims to provide the knowledge that vehicle operators and intervention suppliers need in order to conduct a robust test in which complete faith can be had in the data produced and subsequent rigorous statistical analysis.

This guide is the result of many years’ experience of ‘live’ testing in a range of various companies with different vehicles and different fuel saving interventions. It is written to help fleet operators evaluate the efficacy of an intervention that claims to improve fuel efficiency and thereby reduce fuel costs and resultant emissions. An intervention in this context is a product or service that claims to improve fuel consumption of a vehicle or fleet of vehicles. Evaluating an intervention that claims to reduce emissions over and above those reductions due to improvements in fuel consumption will be considered in a separate guide. Similarly, computerised routing and scheduling software is not covered in this guide.

There are two main questions to be answered when evaluating a fuel saving intervention:

1. Did the intervention work?

2. Is it economically viable?

An intervention might work, but not be economically viable.

The second question cannot be answered until the first question has been answered. It is therefore of paramount importance the first question is answered with the utmost accuracy. There is a certain amount of repetition in this guide and this is done to reinforce key points that can have consequences, if not applied or considered.

It is strongly advised that this guide is read in its entirety, so as to develop a full understanding of testing processes. There is no need for the reader to be concerned about statistical issues, because these are taken care of by an advanced statistical software programme. The important thing, which is focussed upon here, is to produce a robust test.

It begins in Section 2 with an introduction to IFSITS whilst Section 3 focusses on accuracy and its importance. This is followed by Section 4, which resolves what for many is the worrying issues of statistical matters, which are a cause of concern to both vehicle operators and intervention suppliers. For any owner or operator of vehicles it is important that any intervention being tested does not harm the vehicle. Section 5 concentrates on the no-harm principle to the vehicle or engine. It is also important that the intervention does not make the vehicle illegal and this dealt with in Section 6.

In Section 7 the basics of a project management approach are set out before proceeding to Section 8, which goes into great detail of the actual testing process and also provides examples of flawed test methodologies. Section 9 is essentially a ‘food for thought’ awareness section designed to build upon Section 8 and to help with the organising and managing of a test. The issue of dealing with the data produced by the test including lead and lag effects is discussed in Section 10. An example showing what can be achieved when an integrated long-term fleet wide approach is taken is shown in Section 11. Finally, a short review is conducted in Section 12.

2 IFSITS

To give it its full name, IFSITS is the Imise Fuel Saving Intervention Testing System. It is a scientific approach to the problem of intervention testing. It incorporates a proven methodology to address different situations that can present themselves when testing and a separate stand-alone statistical programme to do the statistical analysis that has confounded and troubled most managers. This statistical programme incorporates powerful and established statistical techniques to determine whether or not an intervention has improved fuel consumption. All statistical techniques have strengths and weaknesses, which is why a suite of these techniques are incorporated into the statistical software. This increases the rigour of the analysis and thereby increases the faith that can be had in the final result.

2.1 UNDERSTANDING FUEL EFFICIENCY

Fuel efficiency tends to be considered in terms of miles per gallon (MPG) or litres per 100 kilometres (L/100km). These two metrics do however need to be carefully considered when vehicles can operate with varying payload weights. The metric to be applied in such a case is energy intensity which incorporates for example, such as items as weight or number of pallets or roll cages. An introduction to the thinking behind energy intensity and its application can be found in Professor Alan McKinnon’s work for the UK Government benchmarking guides. Such as Benchmarking Guide 78 Key Performance Indicators for the Food Supply Chain (McKinnon A, 2003).

One of the advantages of the IFSITS statistical programme is that even if energy intensity is used as the metric, it can still be used to determine whether the intervention has improved fuel consumption of not. Whichever metric is to be used, it is important that it is accurate and this is discussed next.

3 A NOTE ON ACCURACY

Irrespective of whether a trial is being conducted in a laboratory; using an engine dynamometer or a chassis dynamometer (rolling road), a test track or 'live' in operations the goal is an accurate result. An accurate result, irrespective of whether it states the intervention being tested was a success or failure, is one in which everyone can have faith and a genuinely well informed decision be made.

Fuel consumption data is influenced by variables that subsequently produce volatility in the data. Most of the variables can be described as inherent. That is nothing can be done about them. Others are non-inherent, which are those that can be eliminated or mitigated to some extent. Examples of inherent volatility are payload weight, weather conditions and traffic conditions. A good example of non-inherent volatility is shown in Table 1, where vehicle fuel refill data is being used to generate the weekly fuel consumption figures. Filling the vehicle's fuel tank to the same point every time will reduce volatility and improve accuracy in any statistical analysis.

Table 1 Inherent and non-inherent volatility

	A			B		
	Miles	Gallons	MPG	Miles	Gallons	MPG
	220	21	10.48	220	21	10.48
	220	21	10.48	220	17	12.94
	220	23	9.57	220	22	10.00
	220	21	10.48	220	22	10.00
	220	24	9.17	220	28	7.86
Weekly average using daily MPGs'			10.03			10.25
True weekly average	1100	110	10	1100	110	10
Difference due to error			0.03			0.25
			0.3%			2.5%

In the rows under 'A' the natural or inherent volatility (random events) where the vehicle has been refuelled correctly (to the base of the fuel tank neck) every time can be seen. The resultant volatility results in only a slight difference between the true MPG (10.00) for the period and the MPG calculated by averaging the daily MPG figures (10.03). In the rows under 'B' the driver short filled on the second and third refuels and compensated slightly on the fourth refill and fully on the fifth refill. This increases volatility and as shown, can lead to erroneous periodic averages. In this case, erroneous weekly fuel consumption figures. The statistical issues and how they are overcome is discussed in the next section.

4 REMOVING THE PROBLEM OF STATISTICS

The application of simple averages, or rather the difference between the average before and the average after the application of an intervention is not appropriate. As shown in Section 3 fuel consumption data generated under normal operating conditions referred to as 'live' is at best volatile due to inherently random events. Such random events can include traffic conditions, weather, road conditions and payload weight; the list is not exhaustive. In order to deal with the volatility in the fuel consumption data and to ensure accuracy more powerful statistical techniques are required.

Most operators of vehicles and energy consuming equipment will not be aware of which statistical techniques to apply and how to apply them. To remove this obstacle to accuracy an analytical statistical programme has been developed to ensure accuracy and consistency.

The statistical programme is part of IFSITS. It removes the need for an operator or anybody else in the test to be a statistician. There are two stages involved in the application of the statistical programme. The first is involved in the selection of 'test' and 'control' vehicles. The second, is in analysing the fuel consumption data to determine whether or not the intervention had improved fuel consumption.

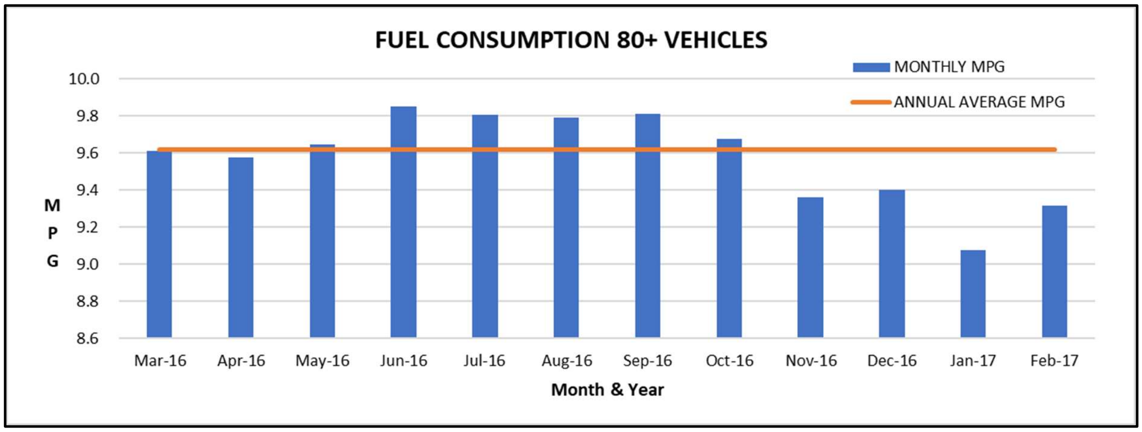
4.1 SEASONALITY

Seasonality in fuel consumption has been found to exist in a number of countries. The patterns, whilst not always identical, can cause problems if seasonality is not considered when conducting a fuel consumption test. Statisticians generally require two years data to show seasonality. Numerous fuel efficiency projects in the UK have all found seasonality.

The main causes of seasonality are the weather, especially wind speed and the change from summer diesel to winter diesel. The latter, which is introduced in October and removed in March is of a lower density and contains less energy. How seasonality can impact upon intervention testing was discussed in 'Basic Steps to Improving Vehicle Fuel Efficiency' (Coyle M 1999).

The impact of seasonality on a test can be mitigated by the use of 'control' vehicles. Where 'control' vehicles are not available the effect of seasonality can be minimised by reducing the length of a test period using the IFSITS system. The ability to minimise the length of a test period is an additional strength of IFSITS. Chart 1 below shows an example of seasonality in fuel consumption in the UK.

Chart 1 Seasonality in fuel consumption



***Note**: Monthly and annual fuel consumption figures are calculated using the correct method described in Table 1. A monthly figure is calculated by the fleets total miles travelled in a month divided by fuel consumed in the month. Annual average is total miles travelled by the fleet in a year divided by total fuel consumed in the year. The fleet did not travel the same distance every month.*

Ideally, knowing the seasonal profile of fuel consumption can help in the planning and management of a test. In certain cases, it might not be possible, due to the lack of historic data or the resources not being available. In which case it is important to know if and when there is a change between winter and summer diesel. It is also important to take an informed systematic approach to select what is to be tested. A key element of which is the 'no-harm' principle.

5 NO-HARM PRINCIPLE

This is an important factor to be considered in any trial where the intervention might harm a component. In the absence of any industry standard tests, or where an industry standard test regime is so expensive that an intervention supplier cannot afford the test, then alternatives need to be considered. For example, when an intervention such as a fuel additive, oil additive or an alternative fuel is being tested on an engine, engine oil analysis is recommended. The analysis should include three samples before the intervention is applied to check that the engine has no problems before the test begins and to determine if there is a trend developing in wear, chemistry and contamination. On-going sampling should take place at agreed intervals during and after the test has been completed. This is important for all concerned, the vehicle owner, vehicle operator and intervention supplier. An example of part of an oil analysis report is shown below in Figure 1.

Figure 1 Example oil analysis report

Sample Date	22/12/2014	21/11/2014	06/11/2014	27/10/2014
Sample #	1628319	1622918	1619832	1617725
Unit Usage	277826	269322	268088	265072
Oil Usage				
Oil Added				
Wear	10	0	0	30
Aluminum	10.00	5.00	4.00	20.00
Chromium	0.00	0.00	0.00	1.00
Copper	3.00	3.00	1.00	27.00
Iron	8.0	4.0	4.0	13.0
Lead	1.00	0.00	0.00	2.00
Nickel	0.00	0.00	0.00	0.00
Silver	0.00	0.00	0.00	0.00
Tin	0.00	3.00	0.00	0.00
Vanadium	0.00	0.00	0.00	0.00
FW Idx	0	0	2	0
Contamination	0	0	0	0
Boron	250.00	288.00	303.00	244.00
Silicon	10.00	10.00	17.00	6.00
Sodium	7.00	14.00	23.00	8.00
IR Soot	32.00	0.00	0.00	54.00
Water K.Fish	0.0	0.0	0.0	0.0
Chemistry	0	0	0	0
Calcium	3,804.00	4,059.00	4,613.00	4,596.00
Magnesium	19.00	14.00	20.00	10.00
Molybdenum	54.00	55.00	65.00	62.00
Phosphorus	1,174.00	1,272.00	1,394.00	1,400.00
Zinc	1,324.00	1,395.00	1,583.00	1,718.00
Manganese	1.00	1.00	1.00	1.00
IR Oxidation	30.00	23.00	25.00	0.00
IR Nitration	53.00	25.00	20.00	0.00
IR Sulfation	47.00	31.00	31.00	18.00
Visc 40C	96.5	100.5	98.5	105.6

In the case of a fuel additive, no-harm testing is essential due to the high cost of fuel systems and small micron clearances between components operating with pressures of more than 2,500 bar. Similarly, with oil additives, the cost of replacing any major part of the powertrain (engine and transmission system) will be very expensive, plus the lost earnings, usually referred to as consequential losses.

It is therefore of extreme importance that an intervention supplier's insurance is checked by a competent individual who is familiar with the language and terminology used in insurance documents. It might be the case that the vehicle operator asks their own insurance broker to check the intervention supplier's insurance to establish whether or not there is satisfactory insurance cover.

6 LEGISLATED STANDARDS AND SPECIFICATIONS

Fuel with an additive added to it needs to be checked to ensure that the fuel remains within the legislated standard. Otherwise the engine could be running on an illegal fuel and it could also have implications for wear and tear of the fuel system and warranty.

Where an additive is being used with a lubrication oil such as engine oil, gearbox oil, transfer box oil or drive axle oil then again oil analysis needs to be introduced as previously described. Lubrication oil with an additive should be checked to ensure that the oil remains within specification.

Any aerodynamic aids fitted to the vehicle need to ensure that they do not cause the vehicle or any trailer that it might be pulling to exceed their legislated maximum dimensions. An example of this was where the fitting of an aerodynamic aid was found to have resulted in a trailer exceeding its swing clearance (Commercial Motor, 2008). Also, to be considered, is any effect upon payload. Where side skirts are being tested thought needs to be given to the potential for damage during loading and unloading from the side by forklift trucks.

When testing a tyre intervention, any impact upon tyre wear needs to be considered in the financial analysis. Additionally, any change in tyre size will have an impact upon the relationship between engine speed and road speed and can change a vehicle’s acceleration rate. Any tyres to be tested should also be checked to ensure they are the correct specification in terms of axle weights.

7 TESTING: PROJECT MANAGEMENT

Testing requires basic project management skills, including communication and project management disciplines. It is important that the test and its purpose is communicated to all members of staff, so that they know what is happening and where necessary, their role in the test. Lines of communication need to be established throughout the company. Basic project management skills such as setting out what will happen and when, sometimes referred to as outcomes and milestones need to be established. Additionally, the responsibilities and authority of individuals involved needs to be set out and communicated to staff. These elements should be recorded in a formal document to ensure that there is a recognised structure to the trial.

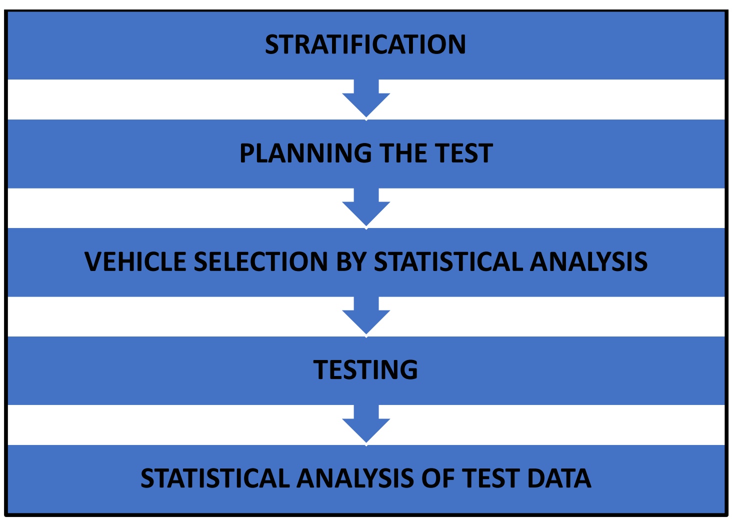
It is important that the company testing the intervention appoints a project manager with sufficient authority to ensure that the testing is done to agreed protocols and procedures. The project manager will be the first point of contact for internal and external people involved in the project.

8 'LIVE' TESTING: A FIVE STAGE PROCESS

For some people 'live' testing can seem a bit daunting, it is possible though to break it down into five basic stages. These five stages form part of the IFSITS methodology, which is a proven scientific approach designed to address the many concerns operators and suppliers of interventions have with regards to 'live' testing. IFSITS includes a statistical programme that selects 'test' and 'control' vehicles and equipment based on being able to obtain the most accurate result; thereby, removing the need for a vehicle operator, equipment operator or intervention supplier to have any knowledge of statistics. Its mathematical programming can also be used to evaluate data generated from testing conducted in a laboratory or test site. For example, on an engine dynamometer, chassis dynamometer and at a test-track or Proving Ground.

In addition to the no-harm principle, vehicle owners will want to ensure that there is adequate insurance to cover any costs incurred should harm take place or is suspected to have taken place. Where harm is suspected it is only fair and proper that an investigation is undertaken by an authoritative and independent body. An overview of how the various processes link together in 'live' testing is shown in Figure 2 below.

Figure 2 Process overview



For a test to be accurate and reliable the process needs to be robust and the statistical analysis rigorous. Ideally there should be more than one 'test' vehicle and several 'control' vehicles. Any test plan must take into consideration operational constraints and the type of intervention being tested. There are two important issues to be dealt with. These are the test process (the robustness) and the statistical processes involved (the rigour).

To remove the problem of non-statisticians dealing with statistical processes an easy to use computer programme has been developed to undertake the necessary statistical process. The test process needs, where possible, to include repeatability with ‘before’, ‘after’ and ‘as before’ conditions. The statistical processes and test processes are both elements of IFSITS, as part of its robust scientific approach to testing. Due to the powerful proven statistical techniques employed in the IFSITS programme the test period can, under certain conditions, be reduced to 30 working days for the most basic test. This enables extended testing, if required, or for staggered testing and reduces the impact of seasonality (Coyle M, Murray W & Whiteing A E, 1998).

8.1 STRATIFICATION

A stratification process is required. This involves matters already discussed in Sections 3 to 7 and a desk-based evaluation of which interventions will have the greatest impact for specific vehicles and their operational profile. It involves considering the different operational profiles of vehicles in a depot, different configurations and separate shift patterns, where vehicles are double shifted.

A financial analysis is also included, which normally has two approaches. The first is the maximum amount of money returned in a specific time period. The second is the fastest payback. It is for the operator to choose their preferred cost benefit mechanism. This process may, or may not, include evidence from laboratory testing such as dynamometer (chassis or engine) or test-track testing, depending upon the category of the intervention and the operator’s view on laboratory and test track testing. Whatever the evidence, it must be viewed dispassionately (Coyle M, Murray W and Whiteing A E 2003).

8.2 PLANNING THE TEST

The ideal test plan would involve many vehicles from which to choose ‘test’ and ‘control’ vehicles. However, this is not always possible, so it is necessary to consider the different test plans available and choose the most robust. The actual selection of vehicles by statistical analysis will be dealt with in Section 8.3.

8.2.1 THE IDEAL TEST

Consider, as an example, all the vehicles in the depot are of the same configuration and have the same operational profile. Different manufacturers vehicles and age profiles are dealt with in the stratification and selection by statistical analysis.

The daily fuel consumption data for the previous three months (this is a minimum) is uploaded to the IFSITS programme to identify and rank the vehicles suitable for inclusion in the trial. For example, where out of a depot fleet of 40 vehicles the IFSITS statistical programme has concluded that only eight are found to produce data good enough to warrant their being included in a ‘live’ trial. The potential for these eight to be used in the trial is then discussed with the local management for their input. There is no point placing a vehicle in a trial if it is about to be replaced, or if there is some other operational reason for an exclusion.

With the ‘test’ and ‘control’ vehicles identified by statistical analysis and confirmed through the knowledge of the local management the ideal test will enable both ‘intra’ and ‘inter’ analysis. ‘Intra’ is where an individual vehicle’s data is analysed based on its own baseline and then its own data generated during the test period. Where possible, if the intervention can be removed or switched off, then an ‘as before’ period can be used to generate data, which can then be analysed against the ‘after’ data, which is the data generated when the intervention was applied. In this case a double check has been facilitated. ‘Inter’ vehicle analysis is where a single ‘test’ or ‘test’ vehicles are compared against the ‘control’ vehicle or vehicles.

Depending upon what the intervention is, it should where possible, be introduced in a staggered manner. Of the eight selected vehicles, three might be chosen as ‘test’ vehicles and five as ‘control’. Should a ‘test’ vehicle be damaged or taken off the road for some reason then a ‘control’ vehicle might - depending upon the intervention - become a ‘test’ vehicle. This also fits into a staggered introduction plan.

The baseline period of thirty days does not delay the start of the trial because the data has already been deemed acceptable by IFSITS. This baseline data from the chosen vehicles is a continuation of the data from when the analysis to select ‘test’ and ‘control’ vehicles was performed. With the establishment of 30 days of baseline data the intervention can be applied.

Fuel consumption data submitted daily reinforces the quality of the test and is important as an element of the project management discipline. If there is an unexpected change in the fuel consumption data, it could indicate a change in the operational profile or vehicle condition. In Figure 3 there is only the ‘test’ vehicle. In this case ‘intra’ vehicle analysis can be conducted between the first baseline data (days 1 to 30) and the fuel data from when the intervention is applied (days 31 to 60). The intervention is then removed or switched off after the end of work on day 60 and an ‘as before’ baseline period is produced (days 61 to 90). This enables a second ‘intra’ vehicle analysis to be conducted.

Figure 3 Single test vehicle with no control vehicle

	TEST VEHICLE
Days 1 to 30	Baseline
Days 31 to 60	Intervention applied
Days 61 to 90	Intervention removed/Baseline

In Figure 4 below there is at least one ‘control’ vehicle available. This enables both ‘intra’ and ‘inter’ vehicle analysis. The degree of difference between both vehicles’ baseline periods (days 1 to 30 and 61 to 90) can be analysed and compared to the degree of difference between days 31 to 60 for both the ‘test’ and ‘control’ vehicles.

Figure 4 Test and control vehicles not staggered

	TEST VEHICLE	CONTROL VEHICLE
Days 1 to 30	Baseline	Baseline
Days 31 to 60	Intervention applied	Baseline
Days 61 to 90	Intervention removed/Baseline	Baseline

Staggering the introduction of an intervention ensures a more robust trial and will increase the trial period. It helps to increase robustness through introducing repeatability. A staggered test enables repeatability and when conducted with a ‘control’ vehicle also permits ‘intra’ and ‘inter’ vehicle analysis. This is potentially the most robust testing format. It can be seen in Figure 5 that both ‘test’ vehicles (Test 1 and Test 2) can be subjected to a major analysis. Test 1 and Test 2 can be subjected to ‘intra’ analysis both ‘before’, ‘after’ and ‘as before’. The red area represents days when the intervention is applied and the blue when no intervention is applied.

Figure 5 Staggered testing with more than one vehicle

DAYS	TEST 1	CONTROL 1	TEST 2	CONTROL 2
1 to 5	Baseline data	Baseline data	Baseline data	Baseline data
6 to 10	Baseline data	Baseline data	Baseline data	Baseline data
11 to 15	Baseline data	Baseline data	Baseline data	Baseline data
16 to 20	Baseline data	Baseline data	Baseline data	Baseline data
21 to 25	Baseline data	Baseline data	Baseline data	Baseline data
26 to 30	Baseline data	Baseline data	Baseline data	Baseline data
31 to 35	Test data	Baseline data	Baseline data	Baseline data
36 to 40	Test data	Baseline data	Baseline data	Baseline data
41 to 45	Test data	Baseline data	Test data	Baseline data
46 to 50	Test data	Baseline data	Test data	Baseline data
51 to 55	Test data	Baseline data	Test data	Baseline data
56 to 60	Test data	Baseline data	Test data	Baseline data
61 to 65	Baseline data	Baseline data	Test data	Baseline data
66 to 70	Baseline data	Baseline data	Test data	Baseline data
71 to 75	Baseline data	Baseline data	Baseline data	Baseline data
76 to 80	Baseline data	Baseline data	Baseline data	Baseline data
81 to 85	Baseline data	Baseline data	Baseline data	Baseline data
86 to 90	Baseline data	Baseline data	Baseline data	Baseline data
91 to 95	Baseline data	Baseline data	Baseline data	Baseline data
96 to100	Baseline data	Baseline data	Baseline data	Baseline data

Both Test 1 and 2 vehicles can also be subjected to ‘inter’ vehicle analysis with Control 1 and Control 2 vehicles. This level of analysis using the IFSITS statistical programme’s powerful proven statistical techniques minimises the potential for events not linked to the intervention to be responsible for an improvement in fuel consumption.

Whilst only two ‘test’ and two ‘control’ vehicles are shown in Figure 5 more ‘test’ and ‘control’ vehicles can be involved, subject to them being selected by both IFSITS and the local management.

8.3 VEHICLE SELECTION BY STATISTICAL ANALYSIS

Random selection of vehicles whether they be ‘test’ or ‘control’ is not the most scientific approach. It increases the risk of selecting vehicles with high levels of volatility in their data, which leads to less accurate analysis and poorer decision making. The vehicles that will provide the most accurate results are those selected by analysis conducted by the statistical programme in IFSITS. The vehicles are ranked according to their level of accuracy and a cut-off point is applied. Vehicles beyond the cut-off point should not be considered for involvement in the test. The ‘test’ and ‘control’ vehicles selected by the statistical analysis are then discussed with the local management to maximise the robustness and accuracy of the test. The importance of the local management knowledge should never be underestimated. If no vehicles are selected by the statistical analysis, then IFSITS can be applied to help the operator to improve the quality of their fuel consumption data management.

It is not always possible to conduct an ideal test, subsequently other considerations come into play.

8.4 FULL DEPOT TEST – NO CONTROL VEHICLES

In some cases, such as a fuel treatment of bulk fuel tanks it might not be possible to have separate ‘test’ and ‘control’ vehicles. In this case it might be suggested to use another depot as a ‘control’ depot. This is risky and should only be considered after the application of common sense and statistical tests have been undertaken. The common-sense approach involves ensuring that vehicles in the ‘test’ and any potential ‘control’ depot are similar and have comparable operational profiles. The statistical tests include checking the correlation in the depots’ weekly fuel consumption figures over a lengthy period. Even with a strong correlation, one greater than 0.8 absolute, an additional check is required.

This additional check is a weekly difference analysis. An example of which is shown in Table 2. The correlation between Depot A and Depot B is 0.84. However, the weekly differences are not consistent and fluctuate between -0.39 MPG and -0.07 MPG. Therefore, it would be unwise to use one as a ‘control’ depot.

Table 2 Two nearby depots

	DEPOT A	DEPOT B	DIFFERENCE	
Week	MPG	MPG	ABS	%
11	9.41	9.80	- 0.39	-4.15%
12	9.24	9.57	- 0.33	-3.55%
13	9.55	9.76	- 0.21	-2.21%
14	9.62	9.80	- 0.18	-1.88%
15	9.49	9.82	- 0.32	-3.41%
16	9.80	9.93	- 0.13	-1.36%
17	9.65	9.72	- 0.07	-0.74%
18	9.53	9.83	- 0.29	-3.06%
19	9.70	9.95	- 0.26	-2.65%
20	9.63	9.71	- 0.09	-0.90%
21	9.83	10.02	- 0.19	-1.94%
22	9.97	10.03	- 0.07	-0.68%

Due to their being no consistency, any improvement in either depot will be distorted by anything between -0.39 and -0.07 MPG due to their negative values. The lack of a consistent difference can have a significant impact on the outcome and a false result generated. In this particular example the difference could be up to -0.32 MPG (-0.39 to -0.07) a considerable amount, which carries a lot of risk with it. The average of the MPG data in Depot A is 9.60 MPG and 0.32 MPG represents 3.3%, so a potential intervention improving fuel consumption by 5% could end up showing 1.7%.

To use another depot as a ‘control’ depot both common sense and statistical analysis must confirm that it is viable.

Therefore, the solution is to apply an ‘intra’ depot analysis. This where all the core vehicles are subjected to ‘intra’ vehicle analysis on both an individual and group basis. Only core vehicles should be used in the analysis. That is vehicles that are producing fuel consumption data regularly in the total period under analysis and removing any vehicles that have undergone any major maintenance or operational changes that may influence their fuel consumption. The data from the core vehicles baseline is compared against the data from the core vehicles’ thirty days in test condition. If possible, an ‘as before’ period for the core vehicles can be undertaken and the data compared with the test period data.

8.5 COMPARISON WITH LAST YEAR’S DATA

Comparing recent fuel consumption data with data generated the same time last year is not recommended for several reasons. It is highly unlikely that the weather conditions are the same. Has the operational profile remained the same? What were the road conditions, were there any major roadworks, then or now? Only core vehicles that were active during the complete period (last year and now) can be included in the analysis. Vehicles that were active last year, but not currently, need to have their data excluded. New vehicles active now, that were not active in the same period last year also need to have their data removed. Any remaining vehicles need to have their maintenance records checked to ensure that no major maintenance work had been undertaken that could have influenced their fuel consumption.

Table 3 shows the weekly differences in MPG at the same depot between two consecutive years. It can also be seen that there is no consistency and the differences are both negative and positive. The range of difference is 0.67 MPG (0.29 to -3.9).

Table 3 Consecutive years

	Year 1	Year 2	Difference	
			Abs	%
Wk 11	9.46	9.41	0.05	0.6%
Wk 12	9.53	9.24	0.29	3.1%
Wk 13	9.56	9.55	0.02	0.2%
Wk 14	9.57	9.62	- 0.05	-0.5%
Wk 15	9.56	9.49	0.06	0.7%
Wk 16	9.57	9.80	- 0.23	-2.4%
Wk 17	9.35	9.65	- 0.30	-3.2%
Wk 18	9.64	9.53	0.10	1.1%
Wk 19	9.57	9.70	- 0.13	-1.3%
Wk 20	9.80	9.63	0.18	1.8%
Wk 21	9.69	9.83	- 0.14	-1.5%
Wk 22	9.59	9.97	- 0.38	-3.9%

This shows why it is inadvisable to compare fuel consumption data produced this year with fuel consumption data produced at the same time last year.

8.6 A NOTE ON LONGEVITY

How long the impact of an intervention is maintained – its longevity – needs to be factored into any cost benefit analysis. If it is a one-off cost with a permanent impact it is a simple analysis. If it is an on-going treatment such as a fuel additive the cost benefit analysis is still not too difficult. Where periodic dosing or treatment is required the question arises as to what the minimum dosage is to achieve the maximum effect and at what frequency.

Any additional maintenance or renewal costs need to be included to ensure that the economic or payback analysis reflects the true costs and benefits. A good example of this is side skirts. In the UK these side skirts can be damaged by forklift trucks when curtain side bodies and semi-trailers are being loaded or unloaded. The cost of any repairs or replacement needs to be considered, plus any cost attributable to time out of operations, where applicable.

Another example would be the case of energy efficient tyres. What is the tyre life compare with standard tyres? Energy efficient tyres have been found to have less tread depth than standard tyres. Any fuel savings have to be considered against any increase in tyre replacement costs.

9 THINKING ABOUT TESTING

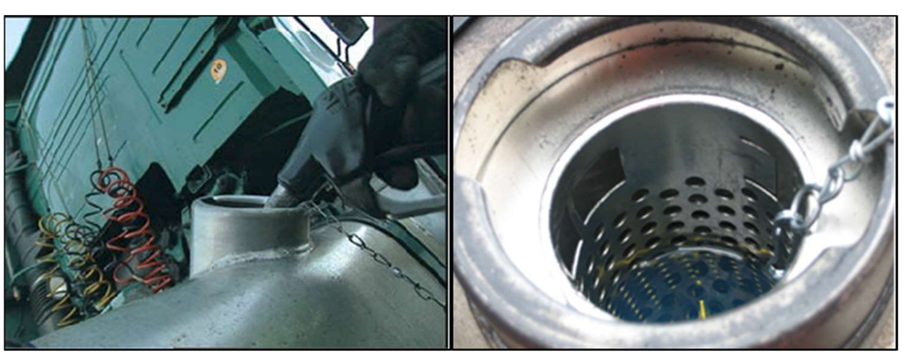
Experience is a hard teacher and can also be expensive. In the following sub-sections are examples of some of the issues that have arisen and how they were overcome. Some were identified before they impacted upon the test, others actually impacted during testing and had to be dealt with. When these situations occur stress levels go up, resource requirement increases and relationships between everyone involved can become strained.

9.1 DATA MANAGEMENT

When a vehicle is being double shifted it is important to be able to separate out the fuel consumption between the different shifts. One problem that occurs sometimes is that the night shift driver does not fill the vehicle's fuel tank, or only partially fills the vehicle's fuel tank. The day shift driver fills the vehicle's fuel tank fully. The fuel records from the vehicle refill records risk being less than accurate.

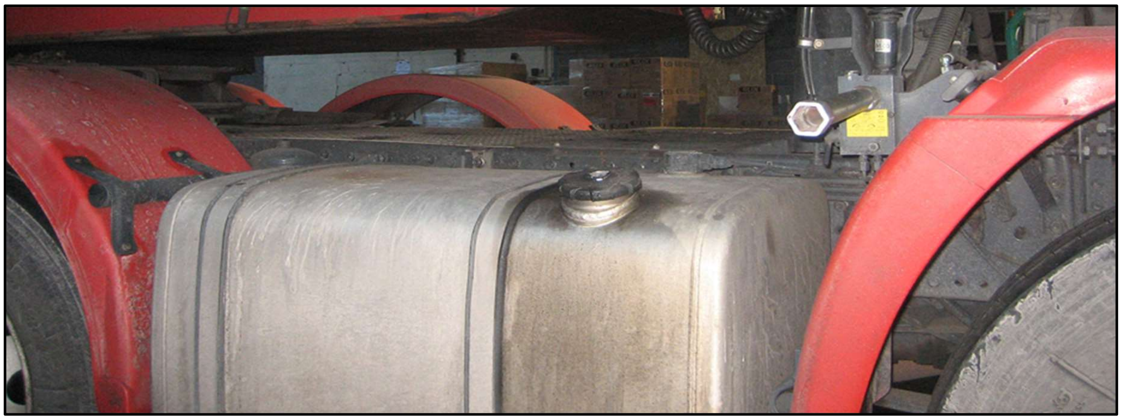
A good telematics system should in the case of a double shifted vehicle be able to separate out the two different sets of fuel consumption data. If using a vehicle's tank refill records, it is important that drivers fill to the same point every time they refuel. It is strongly advised to fill to the base of the neck on a large vehicle where it is possible to see the fuel level, as shown in Figure 6.

Figure 6 Refuelling to the base of the neck



On a smaller vehicle it is advised to fill to the second or third auto cut off on the fuel pump gun. Never fill up to the top of the neck on a vehicle, because fuel can spill when the vehicle is turning, such as when at a road junction or a roundabout. Also, fuel expands when it gets hot due to hot fuel being returned from the engine. In the summer, the sun shining on a fuel tank can also heat up the fuel in the tank as the tanks are easily exposed to the sunlight as shown in Figure 7.

Figure 7 LGV fuel tanks easily exposed to sunlight



Whilst there have been numerous investigations into the difference in fuel consumption between the figures from a vehicle's CANbus, which feeds requested data into the telematics system and vehicle refuelling records, it has been found that these differences have reduced over the years. There is still a difference, but it is now much smaller. A datum test discussed next in 9.2 conducted before the implementation of the intervention can give an insight into the degree of difference and what to do about it.

Most vehicles now have a telematics system fitted to them. The telematics system transmits data from the vehicles CANbus system. The degree to which the telematics system can provide an insight into the fuel consumption can vary between different telematics systems suppliers and different vehicle manufacturers CANbus systems.

For example, being able to separate out fuel consumption when the vehicle is actually in motion from engine idling and fuel consumption when a Power Take Off (PTO) is operating is important. Additional helpful information would include vehicle weight and the generation of a record every time the ignition key was activated, an example of which is shown in Table 4.

Table 4 Telematics data by ignition on-off switch

Ign On (h:m:s)	Ign Off (h:m:s)	Trip Time (h:m:s)	Drv Time (h:m:s)	Distance (km)	Av Spd (km/h)	Over Spd (h:m:s)	Over Spd (Count)	Max Spd (km/h)	Idle Time (h:m:s)	Over Rev (h:m:s)	Over Rev (Count)	Max RPM	Eco-nomy (%)	H Brake (Count)	Fuel Used (litres)	Fuel (mpg)	Driver
23:53:17	00:59:59	01:06:42	01:06:13	69.85	63	00:00:00	0	95	00:00:00	00:00:00	0	1800	80.3	0	20.43	9.66	Unknown
01:00:00	02:08:50	01:08:50	00:47:45	40.62	51	00:00:00	0	93	00:09:16	00:00:00	0	1600	50.8	0	11.30	10.15	Unknown
02:57:04	03:02:53	00:05:49	00:02:12	0.41	11	00:00:00	0	15	00:00:00	00:00:00	0	1020	1.5	0	0.31	3.74	Unknown
11:12:45	11:15:38	00:02:53	00:01:44	0.24	8	00:00:00	0	21	00:00:00	00:00:17	1	2120	43.3	0	0.89	0.76	Unknown
15:16:33	15:24:09	00:07:36	00:00:44	0.06	7	00:00:00	0	10	00:00:00	00:00:00	0	810	0.0	0	0.29	0.78	Unknown
15:33:36	15:35:01	00:01:25	00:00:00	0.00	0	00:00:00	0	0	00:00:00	00:00:00	0	640	0.0	0	0.07	0.00	Unknown
15:40:16	15:57:09	00:16:53	00:16:12	12.67	47	00:00:00	0	72	00:00:00	00:00:00	0	1790	24.0	0	3.12	11.47	Unknown
16:03:36	16:04:25	00:00:49	00:00:00	0.00	0	00:00:00	0	0	00:00:00	00:00:00	0	710	0.0	0	0.03	0.00	Unknown

Courtesy of Btrack Solutions Limited

9.2 DATUM TEST

The aim of the test is to check the accuracy of an individual vehicle's CANbus system against 'tank to tank' refills. The reason for the test is that CANbus based fuel consumption data tends to provide a superior fuel consumption figure than the' tank to tank' figure. Two data points are required, a start datum point and an end datum point. It is strongly advised that the telematics data be displayed in litres to ensure maximum resolution and accuracy. The test is explained using Table 5.

Table 5 The datum test

DAY	DATE	ODOMETER	CANbus	REFILLS
		MILES	LITRES	LITRES
Wed	21/03/2018	105366	56353	189
Thu	22/03/2018	105726		190
Fri	23/03/2018	106079		191
Mon	26/03/2018	106431		188
Tue	27/03/2018	106784		187
Wed	28/03/2018	107137		189
Thu	29/03/2018	107497		192
Fri	30/03/2018	107852		189
Mon	02/04/2018	108206		188
Tue	03/04/2018	108558		192
Wed	04/04/2018	108911		191
Thu	05/04/2018	109262		189
Fri	06/04/2018	109616	58561	190
	Miles travelled	**4,250**		
	CANbus Litres		**2,208**	
	Refill litres			**2,276**
	CANbus MPG		**8.75**	
	Refill MPG			**8.49**

The start datum point begins when the vehicle is refuelled to the base of the neck and the total fuel consumed figure is recorded. In Table 5 this is the 21st March 2018, where the total fuel consumed figure is provided by the CANbus and displayed by the in-cab display. Care must be taken to ensure that the figure is the total fuel consumed since the engine first became operational. The refill fuel dispensed from the fuel pump at this start datum point must not be incorporated into the final calculation of fuel issued.

The vehicle is then operated as normal for several thousand miles or even for up to three to four weeks, being refuelled as normal. Once the distance or time that was decided to be the end datum point has been reached the vehicle's fuel tank is again filled to the base of the neck and the CANbus total fuel consumed figure is recorded from the in-cab display. In this case in Table 5 it is the 6th April.

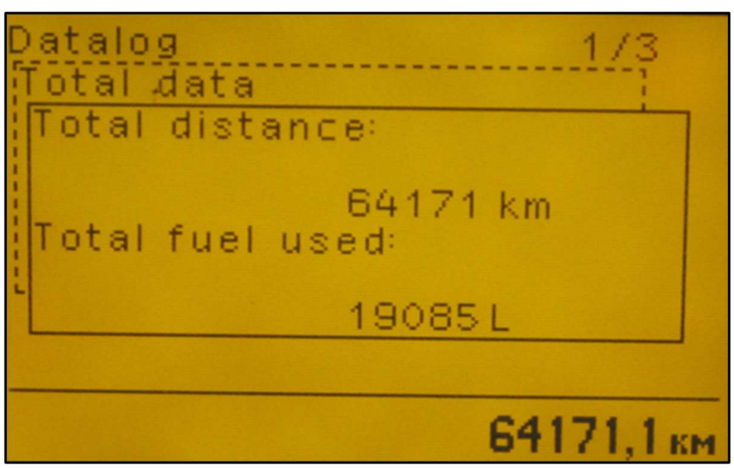
A. The first number (start datum point - 21st March) is subtracted from the second number (end datum point - 6th April) to show the CANbus based litres of fuel concerned. In this case 2,208 litres.

B. During the same time period the data (refills) from the bulk tank dispenser system is collected and the total fuel dispensed calculated. Plus, any fuel card refills if appropriate. In this case 2,276 litres Note it is refills from 22nd March to 6th April.

C. The difference between the figure in A above and the figure in B above is then calculated and expressed as a percentage of B. In this case it is 3.0% ((2,276 – 2,208)/2,276).

To access the necessary information, the menu display will have to be operated in order to bring up the total distance and total fuel consumed data. An example is shown in Figure 8.

Figure 8 In-cab display of total distance travelled and total fuel consumed



The menu can be used to display a large range of information in both metric and imperial units.

9.3 DRIVER BEHAVIOUR

This is a key issue, because a driver can drive in a habitual style. What is meant is that instead of taking advantage of increases in torque and power or reductions in aerodynamic or rolling resistance the driver still changes gear where he has always changed gear on a regular route. Fuel consumption improvements due to the increase in torque and the vehicle not requiring a down shift are thus not realised. This is why it is important that drivers are fully briefed upon what is happening and what is required of them. The use of automatic gearboxes or an automated manual transmission (AMT) can help to mitigate this problem, provided that the drivers do not use a manual override.

Whilst conducting a trial at a test track it was found that the difference between travelling at a constant road speed in seventh gear as opposed to eight gear was to be a 13% deterioration in fuel consumption. The driver was driving in the green economy band on the rev counter. In seventh gear the driver was at the top of the green band in eighth gear the driver was near the bottom of the green band.

9.4 MAINTENANCE ISSUES

Normal routine servicing generally does not have a noticeable impact upon fuel consumption. However, it must be recorded that a routine service has taken place. including the date, time and odometer reading. Tyre pressure records are also important.

Any non-routine work done on the vehicle must also be recorded, including work done, components changed and the date, time and odometer reading. For example, changing fuel injectors, resetting valve tappet clearances and changing a turbocharger. All of which could have an impact upon fuel consumption.

If fuel consumption data is being sent to IFSITS daily, then any sudden significant change in fuel consumption will be noticed quickly and can be discussed with the project manager. This important, because causes need to be identified quickly whilst information is still fresh in people's memories.

9.5 AERODYNAMIC AIDS

Two problems that has been found at the initial stage of considering aerodynamic aid interventions are:

1. Should aerodynamic aids be considered?

2. Which aerodynamic aids are cost effective?

Vehicles travelling at high speeds for long distances, such as trunking vehicles will probably benefit from some aerodynamic aids. Vehicles that have a mix of high speed and low speed in their operational profile need an initial investigation as part of the stratification.

Consider the following example shown in Table 6. A vehicle travels 80 miles from its depot early in the morning to reach a large town or city where it does a number of deliveries and collections. It then returns to the depot in the afternoon when traffic is a bit heavier. The return journey is a bit slower and consumes a bit more fuel, due to using lower gears. The management is aware that most of the vehicles time (60%) is spent in an urban environment where aerodynamic aids would be of no benefit.

However, when more detailed data is collected it can be seen that most of the fuel (60%) is consumed at high speeds where aerodynamic aids will be beneficial in a technical sense. The economic analysis depends upon other factors including price of any aerodynamic aids, fuel consumption rates and the price of fuel.

Table 6 Operational profiling for aerodynamic aids

	Distance	Fuel Consumption			Time	Average
	Miles	**Litres**	**Gallons**	**MPG**	**Hours**	**Speed MPH**
Depot to Town	80	40	8.80	9.09	1.5	53.33
Town Driving	70	56	12.32	5.68	4.8	14.58
Town to Depot	80	43	9.46	8.46	1.7	47.06
TOTAL	**230**	**139**	**30.58**	**7.52**	**8.00**	**28.75**

Fuel Consumption: High speed driving 60% ((40+43)/139).

Driving Time: Town Driving 60% ((4.8)/8).

In this example serious consideration should be given to testing an aerodynamic aid.

The second question is which aerodynamic aids should be fitted. Numerous studies have found that most of the fuel savings achieved come from a small number of aerodynamic aids. Savings of up to 80% of the total savings have been found to come from the cab roof deflector alone. Recommended reading on this issue can be found in ‘Basic Steps to Improving Vehicle Fuel Efficiency’ (Coyle M, 1999). More detailed information is available in Good Practice Guide 308: Truck Aerodynamic Styling and Good Practice Guide 2118: The Streamlined Guide to Truck Aerodynamic Styling. Additional information on simple steps such as reducing the cab gap (Coyle M, 2001) and closing the easysheet on a tipper body (Wilcox D, 1999) is also available on the internet.

To eliminate problems and mistakes it is important that a whole team approach is taken. This means involving drivers, operational managers and maintenance personnel.

10 STATISTICAL ANALYSIS OF TEST DATA

For many vehicle operators, how to tell whether an intervention has worked is a major issue and advanced statistical analysis is not something with which most people are comfortable. The IFSITS programme takes the stress out of this by applying a series of proven powerful statistical tests to the data. The data is simply uploaded and the IFSITS programme does the rest. All statistical tests have strengths and weaknesses, which is why IFSITS applies a battery of tests to increase the rigour of the analysis.

It is important to note that the fuel consumption data from 'test' and 'control' vehicles should be forwarded to the IFSITS operator daily. This ensures that any unusual data can be highlighted and questioned quickly with the project manager. Then a decision can be made as to whether it should be used in the analysis or not.

The output from IFSITS at the end of the test can consist of different results. In the first case, all the statistical tests state that the intervention has worked to different degrees. Being different tests, they will produce figures showing different levels of change and reliability in the calculated improvement in fuel consumption. Thereby, producing a range of improvements with which to work. In the second case, all the statistical tests produce figures showing that the intervention has not worked and as in the first case there will be a range of change and reliability figures. The third and more complex case is when you get a mix of answers; one or more of the tests shows an improvement whilst one or more of the tests shows no improvement. At this point the IFSITS statistical programme operator will investigate further using a specially designed algorithm to check the data. It is also a useful tool when there are lead and lag effects in the data.

10.1 LEAD & LAG EFFECTS

Some interventions may not have an immediate effect. For example, in the case of a fuel additive, which is essentially an additive that cleans the combustion chamber. An immediate improvement in fuel consumption is unlikely to happen, it requires a lead time. It might even be the case that fuel consumption deteriorates in the first instance, due to the cleaning process taking place in the combustion chamber. Similarly, when conducting the 'as before' part of a trial there might be a lag effect in that it takes time for the effect of the intervention to wear off.

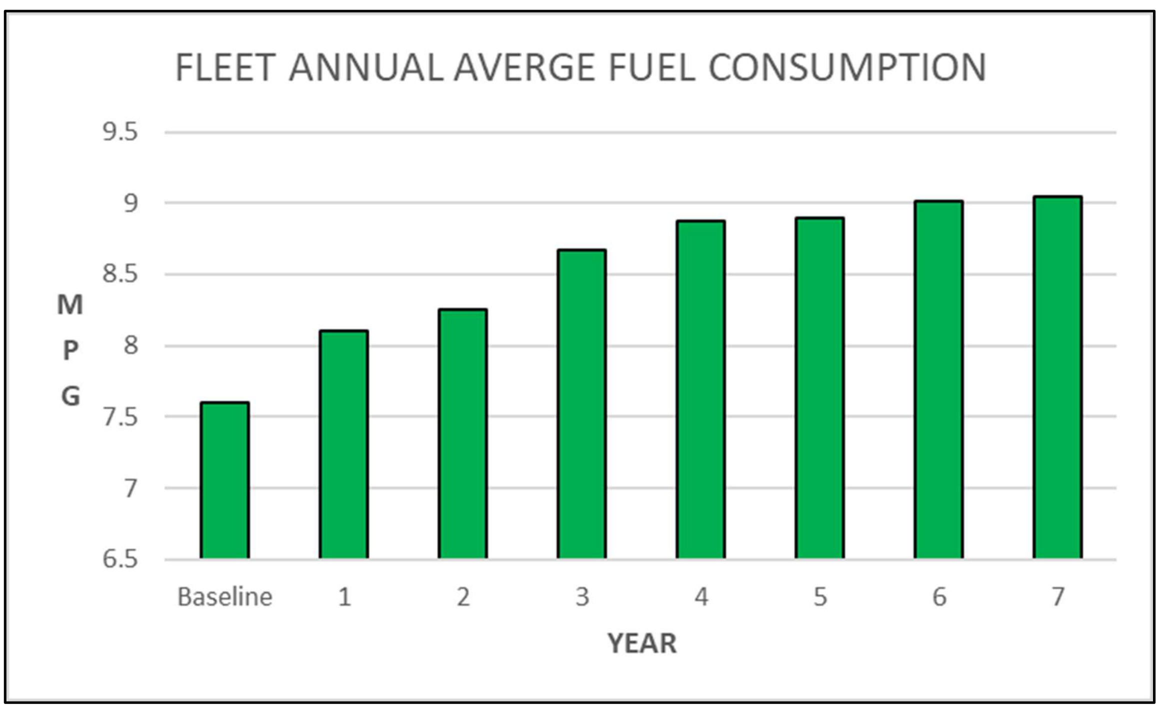
By collecting data on a daily or shift basis - even where the vehicle has more than one driver per day - the IFSITS statistical programme can identify lead and lag periods in the data.

11 GET IT RIGHT AND REALISE THE REWARDS

In some cases, an operator of vehicles might just want to test an intervention that has been brought to their attention. In other cases, there might be a decision made to instigate a fleet wide programme. The following results, from a long-term project, show what was achieved in a major fleet of slightly more than 650 vehicles travelling 56,000,000 miles (90,123,264 kilometres) every year. In the baseline year the fleet consumed 7,368,421 gallons (33,497,505 litres) of fuel. Therefore, the annual fuel consumption in the baseline year was 7.6 MPG (37.17 l/100km).

Vehicles were renewed on a four to five-year cycle and trailers on a ten-year cycle. The interventions applied were many and included changing the vehicle and trailer specifications, which are longer term interventions due to the renewal cycles. The project took seven years to complete and the results can be seen in Chart 2 below.

Chart 2 Annual improvements in fleet fuel consumption over 7 years



By the end of the project the company had improved its annual average fuel consumption by 19.1%, reduced its CO^2 output by 16.0% and at £1.00 per litre reduced it fuel bill from £33,497,505 to £28,130,502. Totalling up the year on year savings, the project saved the company £ £29,139,172 over the seven years of the project.

12 REVIEW

'Live' testing of a fuel saving intervention is a scientific endeavour, incorporating both the knowledge of the operational managers and powerful statistical processes. It is not easy and needs to be managed as a project, incorporating project management skills. Few operational mangers have the statistical skills necessary to conduct the rigorous analysis required to identify acceptable 'test' and 'control' vehicles and then to determine if a fuel saving intervention has been proven to work. That is why IFSITS includes the powerful proven statistical techniques required, thereby negating the need for managers to have statistical skills.

Reducing fuel consumption and emissions is good for business, society and the environment. It is not an easy task and has to be well resourced in terms of staff time and commitment from everyone involved.

This guide has set out how to plan, manage and successfully conclude such a project.

13 SOURCES

Commercial Motor (2008), Don-Bur Answers Teardrop Concerns, 3rd July, p7.

Coyle M, Murray W & Whiteing A E, (1998) Optimising Fuel Efficiency in Transport fleets, June.

Coyle M (1999) Basic Steps to Improving Vehicle Fuel Efficiency. University of Huddersfield 15th April pp 1-2.

Coyle M (2001), Fuel Efficiency and Technical Evaluation Report, BTAC and University of Huddersfield, Saturday 2nd and Sunday 3rd June.

Coyle M, Murray W and Whiteing A E (2003) Fuel Saving Interventions: Facts and Fiction, November.

Coyle M (2004) Results from the Somerfield Fuel Saving Curve (FSC) May.

Good Practice Guide 308: Truck Aerodynamic Styling. 2001, Department for Transport.

Good Practice Guide 2118: The Streamlined Guide to Truck Aerodynamic Styling. 2014, Department for Transport.

McKinnon A (2003), Benchmarking Guide 78 Key Performance Indicators for the Food Supply Chain, Department for Transport.

Wilcox D (1999), Sobering results from sheets-to-the-wind tests, Transport Engineer, Aug, p28.

14 ABOUT THE AUTHOR

Michael Coyle began his career as a Heavy Goods Vehicle (HGV) technician and has subsequently worked as a HGV driver, Lecturer in Vehicle Engineering, Advanced HGV Driving Skills Training Manager, Depot Manager, Logistics Analyst, Project Manager and Research Fellow. Academically, he has a BSc (Hons) in Transport and Distribution, a MSc in Operational Research and his PhD "Optimising the Fuel Efficiency of Large Goods Vehicle (LGV) Fleets" was awarded in 2002. He also has a Certificate in Education (Cert Ed) for lecturing in Further Education.

He has worked on a number of commercial projects for fleet operators, intervention suppliers and UK Government Department for Transport (DfT) schemes. Including three of the four the Fuel Economy Advisor (FEA) schemes, where he was a senior advisor and also trained a number of FEA consultants. He has personally advised more than 100 transport companies and reviewed and reported on over 200 FEA consultants' reports.

Additionally, he led the research project that resulted in the Safe and Fuel-Efficient Driving (SAFED) programme, which was developed with John Boocock. Furthermore, he has conducted research into self-financing fuel bonus schemes for drivers, as one of a range of techniques for sustaining improvements in fuel consumption and was a major contributor to, and appeared in, the UK Government's 'Save It' videos, which were funded by the DfT. In Addition, he was the technical author to the DfT Good Practice Guide: GPG 307: Fuel Management and GPG 313: Fuel Saving Devices. Some of his work with vehicle operators was also recorded in various DfT Energy Efficiency Best Practice Programme (EEBPP) Good Practice Case Studies.

Internationally, from 2002 to 2010 Dr Coyle was an Honorary Programme Advisor to The Department of Automotive Engineering and The Automotive Engineering Database Centre at The Hong Kong Institute of Vocational Education of the Vocational Training Council, Hong Kong. From 2004 to 2012 he was also an Honorary Advisor to the Hong Kong Jockey Club Large Vehicle Testing (R & D) and Emissions Centre. He was the lead consultant on the New Zealand Government's 2008 Fleet Commitment project to ascertain the practices, attitudes, perceptions and barriers to change in relation to introducing fuel efficiency interventions. Additionally, he was the UK member of American Trucking Associations (ATA) Technology Maintenance Council (TMC) Energy Focussed Driver Training Task Force 2010 – 2011.

He has conducted numerous tests on a range of interventions, including, fuel additives, oil additives, low energy tyres and aerodynamics. Tests have involved using engine dynamometers, chassis dynamometers, test track and 'live' in operations (in which he is one of the few recognised specialists having managed or being involved in more than 50 'live' trials). Currently, he is advising and managing testing on a number of energy efficiency and emissions reduction projects.