OPTIMISING FUEL EFFICIENCY IN TRANSPORT FLEETS

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Abstract

It has been suggested that large savings in pollution and operating costs can be made by increasing the miles per gallon (MPG) of Large Goods Vehicles (LGVs). Work undertaken to date in this project has however identified key problems with data management when attempting to analyse fuel consumption. Methodologies to overcome these problems and ensure good quality data have been devised and are being implemented in a group of pilot companies. Once the quality of the data has been ensured then a 'base line' can be established, enabling the testing of a range of interventions, both technical and managerial in nature. An explanation is given as to why seasonal influences should be taken into account when testing any intervention and when examining data provided by suppliers of interventions.

1. Introduction

In 1993 the road transport industry in the UK spent more than £2.5 billion on diesel fuel. It has, however, been suggested that savings of 20% (£500 million) are attainable [1]. Reinforcing this, the Energy Efficiency Office [2] stated that:

> 'Efficient fleets achieve fuel performance up to 20% better than the average'... and ... 'that about 50% of companies do not have effective fuel management or fuel monitoring programmes'.

This therefore raises three questions:
1. Is this statement correct?
2. If it is correct, why is this so?
3. What can be done about it?

To ascertain if the first question is correct, determine why and establish a foundation for doing something about it good quality data is a prerequisite. This paper reports some ongoing work, based on case studies, that began in early 1998.

2. Data quality

Whilst some companies have an abundance of MPG data the quality of a large part of it can be questionable. Errors occur in data for many reasons. Whilst errors that result in outliers are usually ignored or averaged in statistical investigations, in this research the cause of the error is investigated. The purpose is to identify and eliminate the cause, therefore improving data management knowledge and skills whilst ensuring that more accurate data will be available. Error rates found in this and previous investigations have been as high as 20%. (That is, 20% of the total number of records have a field that is incorrect.) For example, a small combined fleet of articulated and rigid vehicles produced 4,900 fuel records for 1997. A record contains data such as date and time of fuel issue, amount of fuel issued, vehicle ID, driver ID, odometer reading, previous odometer reading and an MPG calculation. Table 1 below shows the initial analysis for the uncleaned data applicable to the articulated units in this fleet.

Table 1 : Exploratory Data Analysis of MPG for Articulated Vehicles

Fleet No.	Mean MPG	Std Dev MPG	Minimum MPG	Maximum MPG	Records
A29	131.82	1460.77	0.00	17416.23	142
A50	8.70	1.38	0.00	16.40	130
A51	8.72	0 .92	5.34	13.46	140
A52	8.88	2.97	0.00	27.37	127
A53	9.21	1.70	6.50	26.81	155
A54	9.24	12.62	0.00	163.83	158
A55	9.54	3.55	0.00	29.42	96
A56	9.08	1.93	0.00	12.69	136
A57	9.48	2.15	0.00	25.54	150
A58	8.91	1.74	0.14	15.63	71
A59	9.29	2.67	0.00	19.09	32
A6	102.34	1038.58	0.00	11714.32	127
A60	9.12	2.13	0.47	14.07	28
A65	9.57	1.01	5.41	15.40	292
A7	9.72	3.24	0.00	25.30	115
A74	13.80	30.04	0.00	244.64	140
A78	8.97	1.44	4.32	16.92	104
A79	9.24	1.84	0.05	17.40	76
A8	162.99	810.98	0.00	5673.68	88
A80	15.26	62.88	0.00	693.82	133
A81	21.82	138.53	0.00	1467.82	111
A82	8.62	3.70	0.00	36.35	123
A83	45.89	451.85	0.00	5560.77	151
A85	9.30	2.51	0.00	29.10	102

Total number of observations = 2,927

Clearly the data in Table 1 requires cleansing. Initial analysis identified 660 unusable items of data (550 zero values in the ‘odometer’ field, 65 zero values in the ‘last odometer’ field, 7 missing fleet numbers and 38 records relating to demonstration vehicles). A computer program was developed which filtered out all the MPG values that were less than three and greater than twenty six. From the remaining data all MPG values that were outside the range (mean $\pm$ three standard deviations) for each vehicle, were also removed.

146 observations were removed making the remaining data accurate.
Reasons for erroneous data include:

- drivers not refuelling up to the same level in the vehicle fuel tank

- entering incorrect vehicle registration or ID numbers in the recording system
- entering incorrect odometer readings into the recording system
- tachograph heads being changed and the system being unable to cope with the change or staff not knowing how to include the changes in the system

This cleansing procedure produced the data analysed in Table 2 below.

Table 2 : Exploratory Data Analysis of MPG for Articulated Vehicles after Cleansing

Fleet No.	Mean	Std Dev	Minimum	Maximum	Records
	MPG	MPG	MPG	MPG	
A29	8.95	1.03	4.89	12.92	133
A50	8.76	0.78	6.46	11.51	127
A51	8.68	0.69	6.81	10.62	137
A52	8.66	1.19	3.55	14.96	117
A53	9.06	0.88	6.50	11.60	152
A54	8.41	1.10	3.73	11.19	146
A55	9.27	1.57	5.29	16.99	89
A56	9.43	0.92	6.05	12.69	130
A57	9.63	0.70	7.53	11.50	144
A58	9.01	0.97	5.40	10.25	68
A59	9.28	1.15	6.26	11.08	30
A6	10.37	0.92	7.46	13.88	121
A60	9.26	0.96	7.39	11.26	26
A65	9.56	0.80	6.74	12.23	281
A7	9.61	1.83	6.04	17.65	109
A74	9.50	1.26	4.84	14.41	130
A78	8.89	1.04	5.72	12.34	101
A79	9.25	1.19	5.60	11.55	74
A8	8.87	1.71	5.77	14.95	80
A80	8.45	1.83	3.91	14.59	121
A81	8.55	0.77	6.94	11.09	104
A82	8.25	1.24	4.12	12.46	118
A83	8.61	0.89	5.32	10.44	145
A85	9.29	1.04	5.93	11.8	98

Total number of observations = 2,781

The company concerned has a policy of each driver staying with a specified vehicle on a permanent basis. By comparing the changes in the number of observations the drivers who tend to take greater care with their data can be identified. Following discussions with the operational managers a sample of control and test vehicles can be decided upon.

To negate the Hawthorne effect, the drivers in this particular company have not been told about the project to date. Some interventions can be introduced without the drivers knowing, others will require the drivers being informed. The use of a placebo is being considered to aid in this part of the investigation.

3. Taking Seasonal Variation into Account

Analysis of weekly MPG figures in a range of organisations over several years has revealed a seasonal trend, peaking in the summer (July and August). There then follows a downward trend that bottoms out in January. MPG then begins to rise slightly but falls again, usually towards the end of February and beginning of March. It then begins to rise again until the summer peak. To determine the correlation between naturally occurring seasonality and MPG, Degree Day (DD) data and the highly accurate MPG data of a diesel car has been analysed. DD data is the mean number of degrees by which the outside temperature on a given day is less than the base temperature (15.5^{o}C in this case), totalled for all the days in the period. Further information on DD data is available from the Energy Technology Support Unit (ETSU) [3]. Data for 1996 was used, because in 1997 there was a significant change in the use of the car that affected its MPG, which would have invalidated analysis for that year. Table 3 shows the data and the respective correlation coefficients between variables.

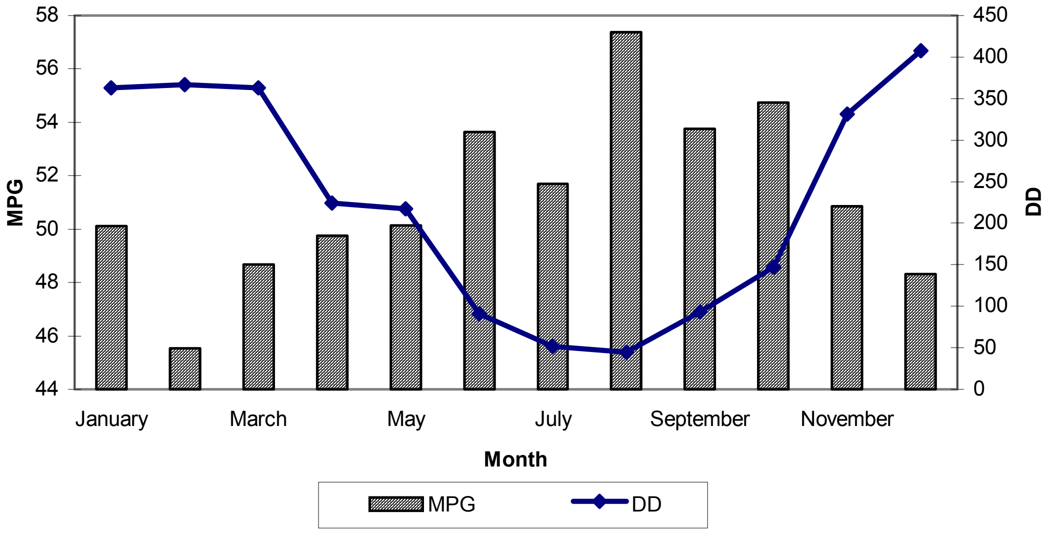
Table 3 : Data and Correlations for 1996

1996	MPG	DD	MILES
January	50.1	363	880
February	45.5	367	522
March	48.7	363	1642
April	49.8	224	1020
May	50.1	217	1314
June	53.6	91	2600
July	51.7	52	1463
August	57.4	45	1655
September	53.8	93	1378
October	54.8	147	1910
November	50.9	331	918
December	48.3	408	1798
Correlation Coefficients			
MPG			
DD	-0.8197		
MILES	0.5497	-0.4704	

The correlation matrix at the bottom of Table 3 indicates a strong negative correlation coefficient (-0.8197) between DD data and MPG. This appears logical in that the colder the weather the greater the fuel used. In depth analysis and testing resulted strongly against the null hypothesis of no linear association between MPG and DD data. Also during the winter months the Government orders the addition of anti waxing additives to diesel and it has been estimated that these additives can cause fuel consumption to deteriorate by up to 3% [4]. The matrix also shows that the correlation coefficient between miles and MPG is much weaker (0.5497) as is the correlation coefficient between miles and DD (-0.4704).

Apart from operational influences it can be seen that natural seasonality as measured by DD data has a major influence upon fuel consumption. Chart 1 shows the pattern of the MPG and DD data from Table 3.

Chart 1 : MPG and DD data patterns in 1996



For any company wishing to test MPG enhancing interventions it is important to understand the seasonal trend and to determine whether they are testing during a peak, a trough, an upward trend or a downward trend. This also reinforces the need for control vehicles in any test. When examining data provided by the suppliers of interventions it is advisable to look at the period in which the ‘before’ and ‘after’ data was collected. Where possible ‘before’, ‘after’ and ‘as before’ testing should be undertaken. This seasonality is clearly very important, but is often overlooked.

4. Management reporting

Management reports on fuel consumption tend to be run weekly or monthly by vehicle operators. Some of the errors previously mentioned are picked up by exception reports. However, other problems in the management reporting system have been identified in the project.

Different computer packages use different values to convert litres (Ltrs) to gallons (Galls) and kilometres (Km) to miles (Mls). Whilst the differences are not large it does indicate the lack of a standard. Three of the monthly management reports recently examined have revealed a more worrying development. Table 4 gives an example of this development using one month's data.

The figures supplied by the management reporting system (from another company in the project) for MPG in column 3 (Man. Sys.) are incorrect. The true MPG as calculated by the Transport & Logistics Research Unit (T&LRU) shown in column 4 shows a reduced MPG. This difference is shown in terms of MPG in column 5 and as a percentage of the Man. Sys. figure in column 6. The difference is shown graphically in Chart 2.

The reasons for the incorrect figures in column 3 (Man. Sys.) have not yet been determined. Due to the fact that the differences between the Man. Sys. and T&LRU are not constant it may relate to how the software deals with certain erroneous inputs from the drivers or outputs from the system (such as outliers) or both.

Table 4 : Problems within Management Reports

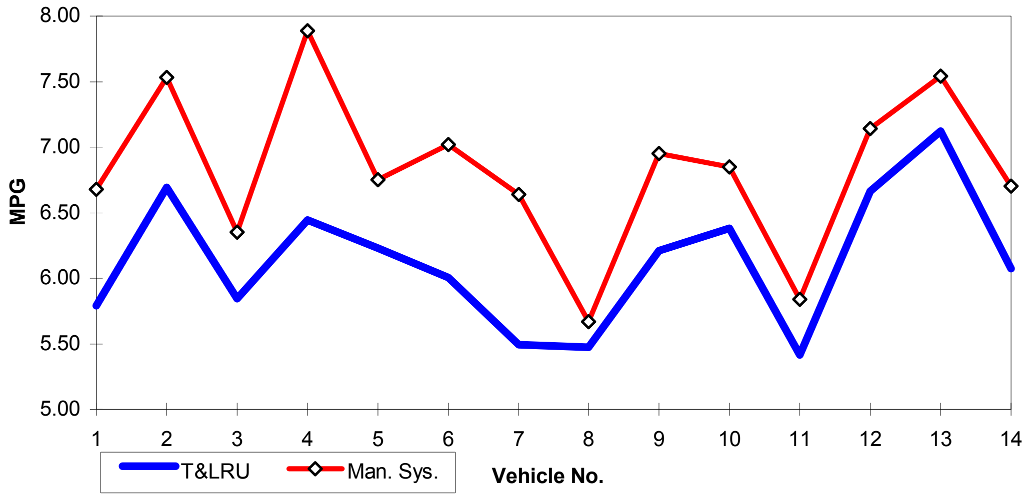
DIST (Km)	FUEL (Ltrs)	Man. Sys. MPG	T&LRU MPG	DIFF MPG	DIFF %
7,985	3,891.20	6.68	5.792	0.888	13.29%
9,022	3,804.91	7.53	6.693	0.837	11.11%
6,522	3,150.51	6.35	5.843	0.507	7.98%
6,884	3,016.10	7.89	6.443	1.447	18.34%
3,288	1,490.00	6.75	6.229	0.521	7.72%
9,428	4,432.82	7.02	6.004	1.016	14.48%
6,920	3,556.18	6.64	5.493	1.147	17.28%
8,771	4,522.19	5.67	5.475	0.195	3.44%
6,819	3,099.23	6.95	6.211	0.739	10.64%
9,295	4,112.04	6.85	6.381	0.469	6.85%
8,139	4,244.15	5.84	5.413	0.427	7.31%
8,765	3,713.15	7.14	6.663	0.477	6.68%
9,623	3,812.94	7.54	7.124	0.416	5.52%
5,700	2,648.78	6.7	6.074	0.626	9.34%
107,161	**49,494**	**6.83**	**6.11**	**0.71**	**10.45%**

↑ $\frac{107161}{49494}$ ↑ 6.83 - 6.11

Note: Slight differences due to rounding.

The figures at the bottom of columns 1 and 2 are the totals of each column. The figure at the bottom of column 3 is the average of all the figures in column 3. The figure at the bottom of column 4 is the weighted average calculated as indicated. The figure at the base of column 5 is the difference as indicated with the figure at the bottom of column six being this difference as a percentage of 6.83.

Chart 2 : Effect of a poor management reporting system



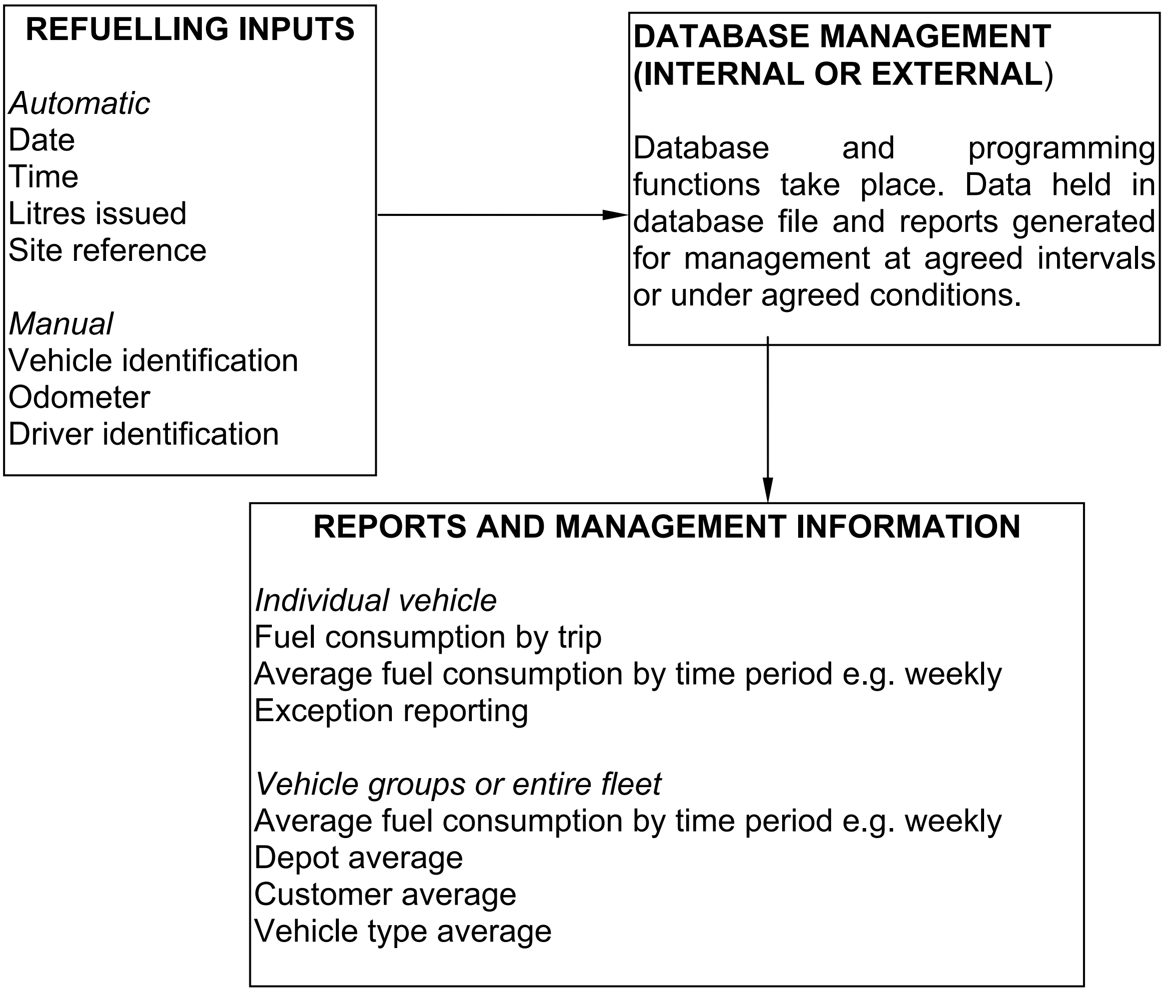
The company budgeting on the basis of the management reporting system will have underestimated its fuel cost in this month for the fourteen vehicles involved by £916 (assuming a diesel cost of £2.40 per gallon). This is the value of the gap between the two lines in Chart 2. The company concerned is in the process of taking this matter up with its fuel supplier who also supply its management reports.

5. Management systems

As previously indicated errors or exceptions may be allowed to stay in the system distorting the MPG figures. By the time a week or even a month has passed there may be so much erroneous data that a considerable amount of management time would be needed to make the necessary corrections. Diagram 1 shows a typical fuel management system. Where refuelling takes place on site it would be desirable to have 'live' exception reporting so errors due to driver inputs can be dealt with immediately. Dealing with errors in this way ensures that the person causing the error can be identified and shown how to undertake the task correctly. This should result in the person not repeating the error. Also by keeping a log of errors, causes and persistent offenders may become apparent therefore enabling a more focused response. For example, training or explaining why fuel tanks should always be filled to the same level.

In Diagram 1, the time gap between the DATABASE MANAGEMENT (INTERNAL OR EXTERNAL) and the REPORTS AND MANAGEMENT INFORMATION assumes critical importance. Whilst some systems will remove or report MPG figures that are highly dubious smaller errors will not be filtered out. When the periodic reports are run these smaller errors can result in incorrect MPG values being indicated and larger standard deviations. 'Live' exception reporting of the MPG figures (using the mean $\pm$ two standard deviations of the previous 30 MPG figures) would ensure high quality MPG data leading to better cost analysis and less management time spent correcting erroneous figures (assuming that they are indeed corrected).

Diagram 1 : Basic Fuel Management System



This data analysis is very important if the environmental and cost benefits are to be realised.

6. The environmental benefits

In environmental terms a diesel engine with a completely efficient combustion process will produce three tonnes of Carbon Dioxide plus other emissions (Table 5) for every 1,000 litres of diesel fuel. Any reduction in fuel consumption clearly has major environmental benefits, by helping to reduce the level of these emissions. For example, an LGV covering 75,000 miles (120,773 kilometres) per year, with an average fuel consumption of 7 MPG will use 10,714 gallons (30,366 litres) of fuel. Raising the MPG by 20% will reduce the fuel requirement to 8,929 gallons (25,305 litres). Subsequent annual savings in emissions can be calculated using Table 5.

Table 5 : Emissions per 1,000 litres of diesel fuel.

Euro specification	*Pre Euro 1*	*Euro 1*	*Euro 2*
Carbon monoxide (kg)	12	12	11
Hydrocarbon (kg)	2	1	1
Nitrogen oxide (kg)	37	21	18
Particulate matter (kg)	5	2	1
Introduction date		1 Jan 1992	1 Oct 1996

Source: Freight Transport Association [5].

7. The financial benefits

Table 6 : Anticipated diesel price 1998 - 2003

Year	£ per gallon	£ per gallon
	Including VAT	Excluding VAT
1998	3.09	2.63
1999	3.31	2.82
2000	3.55	3.02
2001	3.81	3.24
2002	4.09	3.48
2003	4.39	3.74

Source: M Coyle [6]

Reducing the fuel consumption from 10,714 gallons (30,366 litres) to 8,929 gallons (25,305 litres) per annum will save the operator £ 33,804 over the six year period indicated in Table 6. This figure of £ 33,804 does not include a Net Present Value (NPV) calculation and therefore should be considered as a conservative estimate.

The absolute savings to the environment and to any particular company will depend upon the present average MPG. This MPG figure can then be compared to published benchmark figures in the transport press to determine the company's position relative to the average.

8. Conclusion

This paper has concentrated upon the data management issues facing companies who wish to improve their MPG. It has identified problem areas and suggested how such problems can be resolved. If any company is to achieve the potential financial benefits and associated reductions in emissions then accurate data that is well managed is essential.

Whilst the sample is too small to give conclusive answers to the three questions posed at the beginning of this paper the data analysed thus far and interventions being tested would indicate:

1. There is the possibility to improve MPG by 20% or more, and fuel management systems can become more effective.
2. There is a large range of technical and managerial reasons for this state of affairs.
3. Obtaining a base line, based upon quality data with an understanding of the variables involved and the seasonal patterns will assist in the determination of effective interventions.

Sources

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[2] Energy Efficiency Office, *Guide 59 Fuel Consumption in Freight Haulage Fleets* (1996), pp1-2.

[3] Department of the Environment, *Degree Days, Fuel Efficiency Booklet 7, Best Practice Programme*, (1993), pp 1 - 7.

[4] Coyle M., personal communication with engineers at Ricardo Engineering, 1993.

[5] Freight Transport Association, *Environmental best practice guide*, (1997), p22.

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