Research has indicated that, even when all other variables are controlled, significant variations in fuel economy exist which can only be ascribed to the driver. Although several studies have been done to determine whether appropriate educational techniques could improve the fuel economy of the average driver, most have been tests of a small number of drivers conducted under very controlled conditions. While the data from such tests is easily analyzed, the conclusions often cannot be generalized to actual driving conditions. In contrast, this paper discusses some of the problems a researcher may encounter when attempting to analyze data from a large test to determine the effect of driver awareness training on the fuel economy achieved during on-the-job driving of company cars.

Management and analysis of data from an in-use test poses special problems and the test results are often difficult to quantify. However, results from this type of test can give an indication of whether driver awareness training can actually cause a change in the fuel economy achieved during on-the-job driving.

Management of Test Data

Unless instrumentation is used to measure and record the amount of fuel used and the distances traveled, the data collected during an in-use fuel economy test is generally in the form of a log for each vehicle, giving date, odometer reading, and gallons consumed at each fuel purchase during the test period. Even if we can assume that each driver filled up his tank each time he purchased fuel, there can be many problems with using the raw log data. If the data base is sorted by vehicle ID and date, the type of error one can expect are as follows:

(a) Invalid dates (for example, November 61, 1976).
(b) Odometer or gallons number placed incorrectly in its field.
(c) Observations which show a change in odometer readings with gallons consumed equal to zero.
(d) Observations which show no change in odometer readings with gallons consumed not equal to zero.
(e) Odometer readings which do not increase as a function of time.
(f) Observations with odometer readings or gallons consumed which are far out of line with other data for the vehicle.

Errors of types (a) and (e) are often the result of errors in coding the date of a fillup. Because the original log sheets are filled out in chronological order, these errors can usually be corrected by checking the original log sheets. Errors of types (b) errors also tend to be relatively easy to detect and correct. However, there is often no obvious algorithm for correcting the other types of error. This can pose a problem in any analysis of fuel economy. Because the computation of miles per gallon (MPG) for a given observation depends on the odometer readings of observations i and i-1, one cannot merely delete an incorrect observation from the log data file. Also, when the odometer reading or gallons consumed is far out of line for no apparent reason, one cannot merely substitute a data point based on an average MPG number for the vehicle unless the computation of the average MPG does not use the "bad" data point. One solution to this problem is to use the following type of algorithm to compute "average MPG":

Let ODOM = odometer reading
GALL = gallons consumed
i = index for observation number,
K = index for vehicle, and
* = symbol for missing values.

For a given vehicle K,

$$MPG_{K,i} = \frac{ODOM_{K,i} - ODOM_{K,i-1}}{GALL_{K,i}}$$

$$MEAN_K = \text{mean of } \{MPG_{K,i}\}$$

If $$MPG_{K,i} < 1.5$$ or $$MPG_{K,i} > 2 \times (MEAN_K)$$,
then $$MPG_{K,i} = *$$.

$$MEAN_K = \text{mean of } \{MPG_{K,i}\}$$

$$MEAN_K$$ is an average MPG number which gives equal weight to each fillup for which K has valid data, regardless of miles traveled or fuel consumed. In many cases it is desirable to have an average MPG which gives equal weight to each unit of fuel consumed. To compute such an average MPG, AVEK, we continue the above algorithm as follows:

If $$MPG_{K,i} = *$$ then $$MILES_{K,i} = (ODOM_i - ODOM_{i-1})$$ and $$GALLONS_{K,i} = GALL_i$$

If $$MPG_{K,i} = *$$ then $$MILES_{K,k} = GALLONS_{K,i} = 0$$.

$$AVE_K = \frac{\sum_{i=1}^{n} MILES_{K,i}}{\sum_{i=1}^{n} GALLONS_{K,i}}$$

To analyze the changes in fuel economy of a vehicle over time, one can use either the individual fillup MPG numbers for that vehicle or some average monthly MPG for each month the vehicle is in the test. Whatever the chosen measure of fuel economy, the researcher should consider using an algorithm similar to the one
SAS programs to check for and list errors of
analysis. Because programs can be easily written which
require very little data processing knowledge to implement, SAS is a very efficient language for data editing. It is relatively simple to write SAS programs to check for and list errors of
each type discussed above and to replace any obser
vations with corrected data supplied by the
user. Such a system would allow the use of clerical staff to execute the data checking routine, compare erroneous observations with the
original logs, input obvious corrections, and then execute a SAS routine to generate a file
containing whatever MPG data is required.

After completion of all necessary editing, the corrected log data file and the MPG files
must be combined with other available test data. While the contents of the final data base will
depend on the design of the test, the data base
should at least contain the following information
for each vehicle:
(1) Edited driver logs,
(2) MPG files,
(3) Vehicle and driver characteristics (in
cluding group assignment, if applicable),
(4) Dates of entry into the test, exit from
test, tuneup, and education of driver,
(5) Any available data on ambient tempera
ture and driving conditions during the test.
The data can be stored either as a hierar
chical file or as several flat files indexed by
type and treatment group to allow for easy
access to all the data. Because the ease with
which a user can create, store, and merge SAS
data sets, the organization of the final data
can depend solely on projected uses for the

Analysis of Test Data

The purpose of the fuel economy test in question is to determine the effect of driver
awareness training on fuel economy during actual
driving conditions. In reality it is almost im
possible to totally isolate the cause of an ob
served change in the in-use fuel economy of a
vehicle. There are many variables which must be
considered because they may affect the fuel
economy of a vehicle. The effects of some of
these variables, such as vehicle size, transmis
sion type, presence of air conditioning, and age of vehicle, can be controlled in the test
design by stratification of vehicles before ran
don assignment to treatment groups. A test
which utilizes fleet vehicles which are only
driven on the job can also control for variables
such as number of drivers, driving conditions,
and driver characteristics. In contrast, the
effects of variables such as the number of cold
starts, ambient temperature, and tuneup degra
dation are very difficult to control in an in
use test which is conducted over a period of several months. Possible effects of these vari
ables on fuel economy must be considered by any
one attempting to interpret test results. In
addition the effect of the data collection

procedures on driver behavior must be considered.
If it is true that driver behavior affects fuel
economy, the onset of data collection may make
drivers more aware of their driving habits and
thus have an effect on the fuel economy of the
vehicle. Because this effect tends to decrease
over time as a result of the data collection
processes becoming a part of a driver's routine,
it is important that the data collection for an
in-use fuel economy test begin prior to the
actual test period.

In an analysis of the effect of driver
awareness training on the fuel economy achieved
by the driver, it is in general important that
each driver be weighted equally, regardless of
number of fillups, gallons consumed, or miles
traveled. If each driver participated in the
test an equal number of months, the use of each
monthly MPG for each vehicle satisfies this

To determine whether the driver awareness
training had an effect on fuel economy, two
questions need to be answered: (1) Did drivers
who were given driver awareness training achieve
better fuel economy than did untrained drivers?
(2) If so, can this difference be attributed to
the driver awareness training?

Because the test in question is conducted
over a considerable period of time, differences
in fuel economy before and after driver aware
ness training may be due to changes in weather.
Thus the test design should be a comparison
between treatment and control groups which are
determined to be homogeneous prior to treatment.
However, the researcher must realize that, even
with the best design of an in-use test, there
will always be factors other than the treatment
which may affect the test results. Thus the
test may indicate that driver awareness has an
effect on fuel economy but this effect will be
difficult to quantify.

Standard techniques for testing for differ
ences between groups are the t test for two
independent samples and the analysis of variance
to test for differences among two or more sam
ples. However, before doing a t test or an
analysis of variance, one must determine whether
the data satisfy the following criteria:
(1) Random, independent samples,
(2) Dependent variable measured on at least
an interval scale,
(3) Dependent variable is normally distrib
uted in each population,
(4) Populations have equal variances.

Criteria (1) and (2) can easily be satis
fied by the test design. If we are dealing with
a large sample of mean scores, the Central Limit
Theorem applies, and we need not be concerned
about the normality assumption. This implies
that each monthly MPG number to be used in the
analysis should be computed as the mean of the
MPG per fillup for a given vehicle and month.
In addition, with samples of equal size, unequal
variances do not profoundly influence the analy
sis. Thus if criteria 1, 2, and 3 are met and
if each group has the same number of observa
tions, analysis of variance or a t test may be
used. However, with samples of unequal size,
unequal variances can invalidate the results of
either of the procedures. In this case all data

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analysis should be by means of nonparametric statistical procedures which do not require equal variances. (The Mann-Whitney and the Wilcoxon 2-sample tests can be used in place of the t test, and the Kruskal-Wallis K-sample test can be substituted for analysis of variance.) Under SAS76, a user could write his own nonparametric procedure by utilizing the RANK and MEANS procedures. However, the SAS79 NPAR1WAY procedure performs both the Wilcoxon 2 sample test and the Kruskal-Wallis K-sample test, requiring very little effort from the user.

Conclusions

Because there are many variables which affect fuel economy, the researcher must exercise caution in designing an in-use fuel economy test. Even with a good test design and data collection procedure, each observation should be carefully examined for errors, and all conclusions drawn from the test should take into consideration the accuracy of the data and the factors other than driver awareness training which may have had an effect on the test results.