Influencing Travel Decisions using In-car Feedback

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1 - SYNOPSIS

The paper describes research on the impact of car metering on car drivers as a means of influencing car travel demand and in turn reducing fuel consumption.

2 - ABSTRACT

The level of private car usage continues to be one of the major problems in transportation. A reduction in private car use would provide many benefits including the alleviation of congested urban areas and a reduction in energy consumption and transport related pollution emissions. The paper examines one method of attempting to induce a reduction in urban private car use, based on the hypothesis that car owners do not correctly perceive the full cost of a car trip. Such a perception may lead ultimately to misallocation of resources and incorrect decisions relating to the provision of transport infrastructure. The objective of the research is to assess the potential of correcting the misperception by using a digital car meter, installed on the dashboard of a car, which displays on a real-time basis the cost of each trip.

Cost meter information on marginal trip cost and the effect of driving style was provided to a sample of drivers in a pilot-action project in Dublin. Before and after data on the motorists' car trip decisions were collected and analysed. Findings included a significant reduction in car trips in the off-peak period but no significant reductions in time spent travelling, distance travelled and costs of driving as a result of the meter were evident. 40% of subjects when changing their vehicle at a later stage opted for more fuel-efficient vehicles, as a result of their increased cost awareness brought about by the meter.

3 - INTRODUCTION

Understanding the factors influencing driver decision-making is essential if a successful solution is to be obtained to reducing car travel as one measure in traffic demand management. Metcalf (1982) hypothesised that while most of the characteristics which determine travel behaviour within a generalised cost formulation are well understood, the perception of the costs of motoring are weighted incorrectly by car drivers. As a result, the costs of running a car appear to have little effect on car drivers' trip making decisions. Even in cases where feasible alternative options exist car drivers do not take account of the full cost of a car trip, either average or marginal. A method of informing the driver of the real cost of travel may result in more well-informed decision-making particularly those decisions relating to use of the car. Metcalf (1982) and O'Sullivan (1982) proposed a car running cost meter, displaying travel costs in real-time, as a means of informing the driver of these costs.

The findings of O'Farrell and Markham (1975) endorsed the view that most people take only the marginal cost of driving into account. They found that over 60% of the drivers interviewed in a survey considered only the fuel cost of a trip. Metcalf (1982) concluded that car running costs are not considered in the choice of travel mode. It was also hypothesised that car users are probably unaware of the costs of driving both in absolute and relative terms.

An experiment was structured, as a pilot-action funded by EU Energy Directorate, DGXVII, to establish the effectiveness of using such a car running cost meter on driver decision-making and to assess the desirability of staging a larger scale experiment. The experiment involved a sample of ten car drivers in Dublin who used their car to commute to work, but who also had an alternative mode of transport available to them.

In the first stage, the drivers were exposed to the marginal private cost of their trips followed in the second stage by an investigation into the possible use of car meters as a means of influencing driving style by supplying information to the driver on fuel consumption. The response of the driver in each stage was assessed by the use of structured interviews, questionnaires and travel diaries.

4 - METHODOLOGY

The methodology used in the project includes the design of the car meter survey and the meter itself, as well as the design of the behavioural research, such as the criteria to be included when selecting the sample of drivers. Funding allowed for only a small sample but it was sufficient for the purposes of the pilot-action to examine likely problems for the design of a full-scale project. All of the subjects were required to be commuters using their car but with a feasible alternative mode for their work trip to Dublin city centre. The sample included subjects with a wide range of socio-economic characteristics.

4.1. Design of the Car Meter Survey

A combination of travel diaries, questionnaires and interviews was employed in an extensive data collection procedure. The information required of the participants in the interviews was mainly related to choice of route, choice of mode, number of trips made by car, trip chaining and changes in overall quantity of travel. However, the interviews also included questions relating to the participants' assessment of the meter, questions on driver behaviour, driving style, attitudes to public transport and attitudes to cost of travel and fuel efficiency.

To ensure a structured management of the survey it was divided into two separate phases. Phase I concentrated on the reaction of the drivers to the marginal private costs of car travel. The marginal private cost used was a summation of the fuel, the mileage-related depreciation and maintenance costs. Phase II concentrated on driving style, to determine whether a real-time display showing varying fuel consumption at different speeds could influence driving style.

4.2. The Car Meter

The car meter used in the project was designed by the International Ecotechnology Centre at the University of Cranfield as a general information meter to car drivers. However, the meter was reprogrammed to suit the conditions of the experiment. One significant feature of the instrument is that it employs a simulation of fuel consumption and therefore does not require intervention into the vehicle's fuel supply pipes or engine management system (Cousins, 1996). Instead, the meter uses a model specific sensor to detect pulses from the speedometer cable. A specific relationship between this pulse rate and fuel consumption, for which the car meter has been calibrated, is then used to quantify fuel usage.

Information is presented to the driver using a total of five meter functions. These are:

Function 1: Distance (displayed in miles);
Function 2: Marginal private cost (£/∈);
Function 3: Current cost rate (£/∈ for 100 miles of travel *or* mpg)
Function 4: Speed (mph);
Function 5: Marginal external cost (£/∈).

4.3. Calibration Procedure

The meter is calibrated to suit each individual car in which it is installed. The most important part of the procedure is to calibrate the meter against a measured mile so that it can detect the correct distance travelled. The next stage of the procedure is to input the calibration constants into the meter. These relate to fuel costs per litre, miles per gallon for the vehicle, non-fuel costs per mile and congestion costs.

The unit fuel costs were determined by means of a road test which was set up to establish each individual car's fuel consumption values for urban driving conditions. Each driver fills their fuel tank of their car and notes the mileage completed before topping up the fuel tank again. This allowed the miles per gallon actually achieved by the vehicle to be calculated (shown in Table 1).

In the calculation of maintenance costs each driver was requested to estimate the amount they spend on car services so that the marginal maintenance cost related to mileage could be calculated. Depreciation values were taken from Motor Trade Publishers (1997). A summary of the unit costs for all vehicles in the sample are presented in Table 2.

Table 1. Fuel consumption rates

Driver No.	Fuel Consumption of Vehicle in miles/gallon
1	30
2	40
3	30
4	30
5	25
6	33
7	23
8	22
9	29
10	40

Table 2. Vehicle details and unit costs

Model	Year	Engine Size (cc)	Fuel Type	Avge. Fuel Cons. (Km/l)	Marginal Deprec. & Mainten. Cost (∈/mile)	Fuel Cost (∈/mile)	Total Cost (∈/mile)
VW Golf	1980	1300	L	10	0.02	0.08	0.09
Nissan Micra	1988	988	L	14	0.05	0.06	0.1
Range Rover	1986	2800	D	10.5	0.04	0.07	0.11
ToyotaCorolla	1988	1300	UL	10.5	0.06	0.07	0.12
Honda Accord	1989	1989	UL	8.8	0.06	0.08	0.13
Ford Fiesta	1982	1000	L	11.5	0.02	0.07	0.09
Honda Accord	1991	2000	UL	8	0.06	0.09	0.15
Volvo 850	1995	2300	UL	7.7	0.08	0.09	0.17
Honda Civic	1994	1500	UL	10.2	0.06	0.07	0.07
Toyota Starlet	1991	1296	UL	14	0.06	0.06	0.12

Note: L = leaded petrol ; UL = unleaded petrol ; D = diesel

5 - RESULTS

Experimentally, the programme described in Table 1 subjects the group of drivers to four different experimental conditions, namely

- Before
- Private cost displayed
- Fuel consumption
- After

Data from the diaries can be used to determine whether a significant relationship exists between these conditions and a set of independent variables that depend on driver behaviour. The independent variables include of number of trips made, the time spent travelling, the distance travelled and the total cost.

Figure 1 displays the change in the average value of these variables for the before, during and after stages of exposure to marginal private cost. Eight of the drivers showed a drop in the number of trips made when exposed to the private costs of car travel, while the other two drivers' trip totals remained unchanged. In the after stage, that is when the meter was removed, the trip average did not return to that of the before stage. Instead, it remained more or less at the level of demand as the during exposure stage.

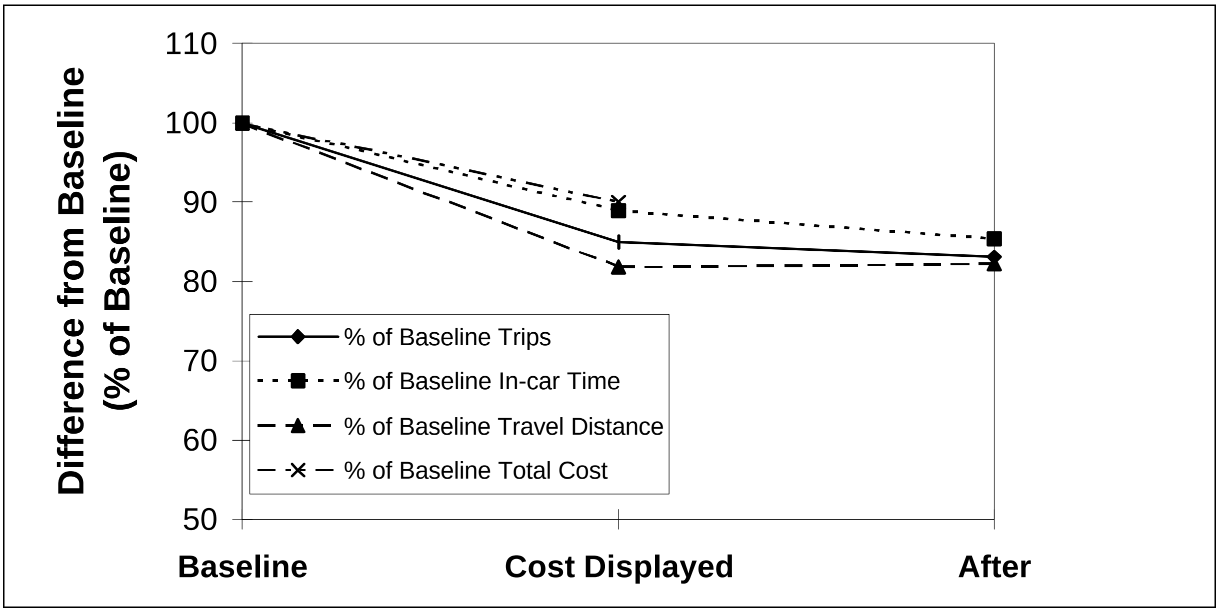

Figure 1 *: Changes in variables*

When examining the effect on the 'time spent in vehicle' variable seven drivers spent less time in their vehicle while three spent more. The average distance travelled in each of the four diary weeks also decreased appreciatively between the before and other stages, suggesting that the inclusion of the meter had some effect on this variable. Figure 1 shows that the total trip costs incurred by the driver, as identified by the meter, also decreased.

It is difficult to ascertain for certain whether the changes in travel pattern described in Figure 1 are actually attributable to the effects of the meter. To investigate this fully, a statistical analysis of the individuals' data is required to determine whether the changes observed are significant, or merely within the range of experimental scatter.

6 - ANALYSIS OF QUANTITATIVE RESULTS

The technique applied in this project of using a single group of drivers for all the experimental conditions is called *repeated measures design* (Lehman, 1995). Instead of randomly allocating a larger number of drivers to different groups so that each group experienced one condition, the drivers were kept in a single group so that each driver experienced all four experimental conditions in succession. In general, the repeated measures design is considered more powerful than using independent groups for each condition. The widely-used Student's t-test is applied to the exposure to private cost data recorded to determine the significance of any observed change in average travel behaviour.

6.1. Number of Trips Made

The number of trips made by drivers under each of the test conditions is shown in Table 3. It can be seen that there is some reduction in the number of trips when the private cost is displayed to the drivers. The t-test result indicates significance values of 0.005. As a value of 0.05 or less is generally considered significant, the statistical analysis would indicate that the changes in the number of trips compared with the baseline data were influenced by the exposure of private cost to the car drivers. A significance of 0.092 was realised for the comparison between the baseline trip data and the trip data taken after the survey, i.e. after the meter was removed. This indicates that the drivers are apparently returning towards their baseline trip numbers.

Table 3. Impact of car meter on number of trips made (all trips)

Driver No.	Base-line	During	Diff. from Baseline (Trips)	After	Diff. from Baseline (Trips)
1	43	40	-3	30	-10
2	43	39	-4	18	-25
3	38	28	-10	28	-10
4	34	25	-9	30	-4
5	37	36	-1	25	-12
6	40	31	-9	45	+5
7	34	29	-5	35	+1
8	27	27	0	23	-4
9	35	35	0	46	+11
10	29	16	-13	19	-10
Mean	36.0	30.6	-5.4	29.9	-6.1
Sig. of change			0.005		0.092

It can be concluded from Table 3 that, within the level of significance stated, the car meter has had an effect on the number of trips made by the drivers. To examine this further, it is interesting to isolate those trips sacrificed by the car driver. Figure 2 shows the number of total trips in each condition segregated by trip purpose classifications: *work, school, shopping* and *social/other.* All work trips were made during the peak period and all other trips were made in the off-peak period. It is evident from Figure 2 that the car drivers appear to sacrifice social and other trips rather than essential trips such as work, school or shopping trips. In fact, work and shopping trips increased marginally.

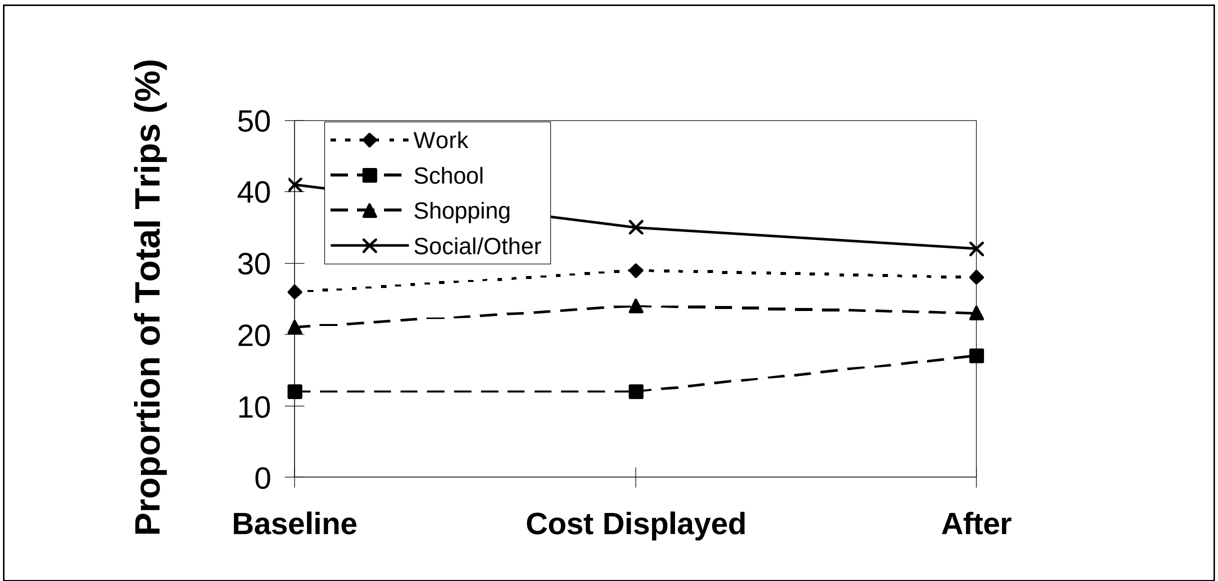

Figure 2 : *Trip purpose classifications*

Table 4 compares the number of social/other trips made by each driver in each condition. With exposure to private costs, the number of these trips decreased by 23%, a reduction significant at just over the 10% level for the private cost case. These data would seem to confirm that the presence of the meter caused drivers to reduce their non-essential trip-making. Table 5 indicates the influence by trip purpose where it can be observed that the impact of the meter on social/other trips is more influential than for other trip purposes.

Table 4. Impact of car meter on number of trips made (social/other trips only)

Driver No.	Base-line	During	Diff. from Baseline (Trips)	After	Diff. from Baseline (Trips)
1	12	12	0	4	-8
2	14	13	-1	1	-13
3	12	4	-8	7	-5
4	2	5	+3	5	+3
5	10	6	-4	7	-3
6	1	1	0	3	+2
7	10	5	-5	6	-4
8	5	5	0	3	-2
9	12	13	+1	19	+7
10	12	4	-8	7	-5
Mean	9.0	6.8	-2.2	6.2	-2.8
Sig. of change			0.102		0.157

Table 5. Impact of car meter on number of trips made (by trip purpose)

Trip Purpose		During	After
Work	% of Before	98	96
	Significance of change	0.879	0.751
School	% of Before	88	127
	Significance of change	0.343	0.322
Shopping	% of Before	102	128
	Significance of change	0.895	0.186
Social/	% of Before	77	69
Other	Significance of change	0.102	0.157

6.2. Time Spent in the Car

The time spent in the car generally decreases for most of the drivers in the sample after exposure to the costs of travel, as can be seen in Table 6. This table shows the time spent in the car in each week as a percentage of the mean distance travelled in the before condition. However, when the significance of this decrease is examined it is not significant. One explanation for the less significant influence of the meter on travel time than on number of trips is that the experimental design concentrated on the journey to work. For many drivers, work trips contribute disproportionately to their total travel time and as there was little impact on work trips, total travel time was not significantly affected.

6.3. Distance Travelled by Car and Cost of Car Travel

The distance travelled by each of the drivers in the Dublin sample for the during and after stages, are compared with the baseline data in Table 6. The table shows the mean distance travelled at each stage as a percentage of the mean distance travelled in the baseline. The t-test results reveal that the influence of the car meter on the distance travelled by car is not statistically significant in contrast to what was found earlier for the number of trips. Similar conclusions to those made for the distance travelled by car variable can be made for the cost of car travel variable.

Table 6. Change in travel variables (all trips)

Measure		During	After
No. of Trips	**% of Before**	**85**	**83.1**
	Significance of change	**0.005**	**0.092**
Time	**% of Before**	**88.9**	**85.3**
	Significance of change	**0.155**	**0.25**
Distance	**% of Before**	**81.8**	**81.8**
	Significance of change	**0.225**	**0.3**
Cost	**% of Before**	**89.7**	**-**
	Significance of change	**0.502**	**-**

7 - QUALITATIVE RESULTS

The interviews conducted with the individuals provide an excellent insight into the drivers' responses and attitudes to the car meter and survey as a whole. Most of the car drivers were impressed with the car meter and found the displays useful and interesting (Byrne et al, 1995). This suggests that displaying travel costs via a car meter is a practical and beneficial means of enhancing car drivers' knowledge and awareness of travel costs. However some of the drivers argued that marginal depreciation and maintenance costs should not be included in the running costs, basing their trip decision making only on fuel costs. A programme of education, revealing the true costs of motoring may therefore be justified. Seven drivers admitted that their awareness of the costs of motoring had been enhanced to some extent.

Most of the sample considered the current cost of fuel to be too low to cause them to consider switching to another mode of transport. In the event of fuel costs being increased significantly, some drivers would reduce trips, while others would buy more fuel efficient cars. This finding reinforces the view that drivers only include fuel costs in their decision making.

Five drivers said their behaviour had been affected by the car meter in some way. One driver made less trips and one driver changed mode for social trips. While six of the drivers said their attitudes, mainly towards the cost of travel, had changed, many of the drivers considered the car to be essential for most of their trips and would not change mode regardless of being informed of the costs.

In the case of exposure to real-time fuel consumption the subjects found this information particularly useful on long journeys where they tended to maximise their fuel consumption by selecting the most economic speed. Within the period of the study, four of the drivers in the sample purchased more fuel-efficient cars with smaller engine sizes. These drivers admitted that an increased awareness of fuel efficiency had influenced their decisions. This was an unexpected result and was noted from interviews conducted with the drivers towards the end of the project. It was evident from the interviews that most subjects had an increased awareness of car travel costs.

8 - ENERGY SAVINGS ASSESSMENT

The above analysis of travel diary data showed an average reduction in off-peak trips of 16%. As the data in Table 5 showed that this decrease was statistically significant, a network transportation model was used to assess the fuel/energy saving that would accrue if a similar 16% reduction in trips was achieved for the whole car-using population of Dublin.

This decrease in trips was modelled by reducing the off-peak travel demand matrix in a network model of Dublin (DTO, 1997) by 16%. In the simulation, this change caused a reduction in congestion, which led to increased travel speeds and reduced distances travelled within the network. These, in addition to the effect of the reduced demand itself, impacted on the total fuel consumption in the modelled hour, causing the number of fuel litres used to drop by 19.6%. It should be noted, however, that this analysis represents an extrapolation of results obtained based on a very small sample and as such, in the absence of further validation through large-scale experimental work, provides only an indication of the potential benefits offered by a universal metering strategy.

9 - CONCLUSIONS

- Car drivers in the sample for the most part underestimated their travel costs. Most drivers appeared to neglect mileage-related costs such as marginal depreciation and maintenance costs.
- In-vehicle meters appear to offer the potential of reducing the demand for car travel by causing a behavioural change on the part of individual drivers.
- While most of the drivers were impressed by the meter and found its output credible, the new information provided was not meaningful enough to cause them to change mode.
- It is noteworthy that when some of the drivers in the sample changed their vehicle, they opted for more fuel-efficient cars and admitted that the enhanced information gained from the survey greatly influenced their decision.
- A reduction of 16% in off-peak trips was observed However, trip making patterns in the peak period did not change significantly.
- The result obtained from the energy savings assessment for Dublin reveals the potential of such meters. This assessment yielded a fuel saving of approximately 19.6%.
- The results of the car meter experiment suggest that some form of in-vehicle instrumentation informing the driver of travel costs, should be built into all new cars. However, confirmation of the findings require both a large scale study and one extended over time.

10 -ACKNOWLEDGEMENT

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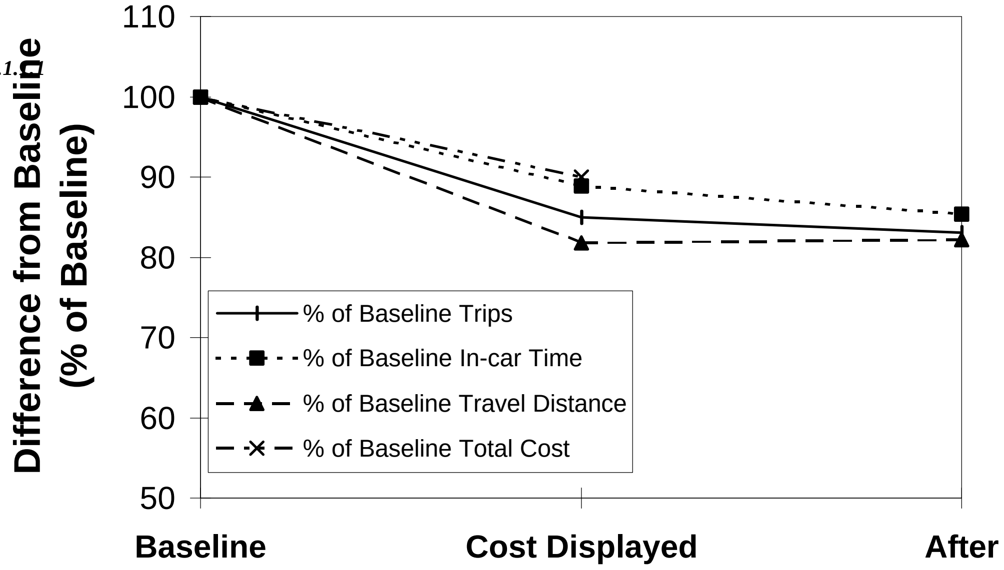
Difference from Baseline (% of Baseline)
110
100
90
80
70
60
50
% of Baseline Trips
% of Baseline In-car Time
% of Baseline Travel Distance
% of Baseline Total Cost
Baseline
Cost Displayed
After

Figure 2 Trip purpose classifications