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The effects of eco-driving motivation, knowledge and reward intervention on fuel efficiency

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ABSTRACT

Every year, bus companies consume millions of litres of fuel, and their fuel costs often exceed millions of US dollars. These companies have an obvious interest in reducing their fuel consumption. One way to encourage drivers to engage in eco-driving behaviours, as well as their related beliefs, is to use a monetary reward system. The aim of this study was to explore the incentive effects of such a reward system to encourage better driving behaviours among bus drivers. This study collected fuel-efficiency data before and after the implementation of a reward system. Furthermore, to study the effects that the system had on driver behaviours, this study adopted the theory of Motivation–Opportunity–Ability (MOA) to construct the regression model. The results for the average fuel consumption efficiency for the buses before and after the reward system was introduced showed an improvement of more than 10% and thus a reduction in carbon emissions.

Introduction

In response to the negative impacts of global warming, many countries are adopting policies to reduce greenhouse gas emissions and fuel consumption. The fuel efficiency of the transportation sector has become a key issue in such actions. According to the United National Framework Convention on Climate Change (UNFCCC) data (UNFCCC, 2007), by 2030, the transportation sector will account for 40% of all new investment in carbon reduction efforts worldwide, the third highest of all sectors considered.

The U.S. Department of Transportation (2010) summarised the strategies for carbon emission reductions in the transportation sector into four main categories: reduced carbon-intensive travel activity (e.g., changes in urban design and land utilisation patterns); improved transportation system efficiency (e.g., increasing the use of public transportation); increased vehicle fuel economy (e.g., popularising eco-driving practices); and development of the use of low-carbon fuels (e.g., promoting the use of electric vehicles). Eco-driving is one way of increasing energy efficiency and has recently attracted considerable research interest (Gense, 2000). It primarily consists of a variety of driving techniques including not driving too fast; not accelerating too quickly; shifting gears earlier to maintain a lower engine speed; keeping a steady speed; and ensuring that vehicles are well-maintained (Barth and Boriboonsomsin, 2009).

Numerous studies have examined the impact of eco-driving training courses on fuel consumption. For example, af Wåhlberg (2007) monitored fuel consumption in buses and recorded a 2% fuel savings in the 12 months after the drivers had undergone such training. The Centre for Renewable Energy Sources of Greece conducted an eco-driving pilot study to

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assess the effects of changing urban bus drivers' driving style. The training courses were designed to increase the drivers' knowledge with regard to more economical driving techniques. The results indicated an overall 4.35% reduction in fuel consumption per kilometre after training courses (Zarkadoula et al., 2007). However, both studies reported that after a period of time, the fuel savings became lower than the levels originally attributed to the courses. Beusen et al. (2009) provided dynamic advice to drivers in an eco-driving course and analysed the long-term impacts on fuel consumption and on different driving parameters. The results indicated that the mean fuel consumption for all drivers after the course fell by 5.8% and that the effect for the group as a whole was permanent up to 6 months after the course. Bart and Beusen, 2013 re-analysed the data used in a previous paper by Beusen et al. (2009). They indicated that a higher ambient temperature resulted in lower fuel consumption. Additionally, this paper still holds that eco-driving courses can yield significant improvements in fuel economy. However, this effect was gradually lost in the months after the course.

Fuel conservation is especially important to bus companies because it can lower operating costs in addition to reducing environmental pollution. The cost per litre of diesel in Taiwan was NT $14.4 in 2000. This cost rose to NT $31.3 by 2013, and fuel accounted for one-fourth of the total operating cost of bus companies. Therefore, the conservation of fuel, in order to lower operating costs, is a vital issue for bus companies. In Taiwan, such companies have adopted a number of fuel use reduction strategies, including vehicle maintenance, vehicle replacement and driver behaviour management. The latter is mainly implemented through training, which can improve drivers' knowledge of eco-driving and encourage them to adopt better behaviours. Therefore, the focus of this study is to examine how to best increase the drivers' willingness to change their practices in this regard.

The approach that this work adopted to promote changes in behaviour was based on behavioural theory. Behavioural theory suggests that an individual's decision-making and behaviours are co-determined by personal characteristics (e.g., motivation and ability) and extrinsic conditions (e.g., opportunities for action) (Lewin, 1951). Rewards are among a number of external structural conditions often used by companies to encourage changes in behaviours and improvements in productivity. Although rewards could be used to encourage eco-driving behaviour, the effectiveness of this approach has not been documented. Therefore, this study used experimental methods to explore the following two issues: (1) the relationship between the eco-driving reward and the driver's motivation and knowledge for eco-driving as a psychological latent variable, as well as the resulting reductions in fuel consumption, and (2) the impacts of eco-driving motivation, knowledge and eco-driving reward on fuel efficiency.

The approach

This study presents a theoretical framework based on the Motivation–Opportunity–Ability (MOA) model (MacInnis et al., 1991) as an explanatory model for understanding the effects of a reward system that correlates the motivation to change driving behaviours, knowledge of eco-driving, and fuel efficiency. The theoretical framework used to evaluate the effectiveness of the reward system is outlined below.

Motivation has been defined as goal-directed arousal (Park and Mittal, 1985) and is commonly viewed as a force that directs individuals toward goals and/or to process information (MacInnis and Jaworski, 1989). Ajzen (1985) theory of planned behaviour (TPB) is one of the most commonly used models to represent an individual's motivation. The TPB model postulates that all motivational factors are determined by three rational determinants: attitude, subjective norm and perceived behavioural control. These three factors combined together lead to the formation of eco-driving intention, which is the immediate determinant of eco-driving behaviour.

Opportunity reflects the extent to which a situation may hamper or facilitate a particular behaviour. An incentive is one of a number of external structural conditions that may mediate the impact of an intervention. Incentives have an active role in pushing an individual's abilities and willingness to take certain action, motivating them to develop skills that can enhance performance in an efficient and effective manner. In the current challenging economic environment, managers require cost-effective ways to motivate employees. Many organisations use non-cash incentives to achieve this motivation. However, academic research has focused primarily on the effectiveness of cash rewards despite the widespread use of non-cash rewards (Dzuranin and Stuart, 2012). Financial incentives can enable individuals to have immediate feedback with regard to their efforts. Therefore, we conducted an experiment to examine how cash incentives can affect fuel-efficiency and the motivation to engage in eco-driving in two bus companies.

Ability is defined as a person's skills or proficiencies (e.g., knowledge, intelligence, and resources) with regard to achieving a specific outcome (Hoyer and MacInnis, 2006). The current study deemed knowledge of eco-driving as the most relevant factor that can affect ability. There is some evidence that suggests that if drivers have more of this knowledge they are better able, and more willing, to carry out the related behaviours.

Data collection

Participants and study design

This study arranged experiments with two bus companies, one with and one without an eco-driving reward system. The experimental group was the company with an eco-driving reward system. This company had 391 standard buses and 85

mid-sized buses, which together drove 21.9 million kilometres in 2011 and consumed 6.2 million litres of diesel. The factors that influenced fuel efficiency included vehicle make and size, route traffic, road conditions, and driving behaviour, with the latter being especially important. For example, fuel efficiency data were collected from 20 drivers driving a bus of the same make, size (medium) and route for one year. The driver with the lowest fuel efficiency had results of 4.39 km/l, while the driver with the highest had 6.31 km/l, and the standard deviation was 0.46.

The experimental bus company began an eco-driving reward system in January 2012 to provide an incentive for drivers to adopt eco-driving behaviours. It set a fuel efficiency standard rate (km/l) based on operating records from the previous year. A monthly fuel consumption standard was obtained by multiplying the standard rate by the planned monthly vehicle-kilometres of a driver. If the actual fuel consumption was less than the calculated fuel consumption standard, a monetary reward of NT $5 per litre saved was given to the driver.

Data from the control group, which had no eco-driving reward system, were also collected to investigate the effectiveness of the reward system. The control bus company had 125 standard buses and 55 mid-sized buses. The data collection procedures used in this work were as follows:

1. Wave 1 of the questionnaire survey of drivers in both groups was conducted in December 2011, before the start of the reward system in the experimental group.
2. The experimental group began implementing the eco-driving reward system in January 2012.
3. Wave 2 of the questionnaire survey of drivers in both groups was conducted in June 2012.
4. The monthly average fuel consumption data were collected for all the surveyed drivers before (January–June 2011) and after the reward system (January–June 2012).

During the first wave, 150 questionnaires were sent to each of the two groups, with 121 effective responses obtained from the experimental group and 112 from the control group. Wave 2 of the questionnaire survey focused on the effective samples from Wave 1. The experimental group had 116 effective samples, and the control group had 105 effective samples, for a total of 221 effective samples.

The descriptive statistics of the samples were summarised as Table 1. The gender distribution of the participants from the usable samples was 220 males and only 1 female, reflecting the demographic composition of bus drivers in Taiwan. The age was mainly distributed between 41 and 60 years old, with a proportion of 71.49%. Approximately 12% of the drivers had a college or university degree. Approximately 80% of the respondents had a monthly income of less than NT $35,000 (roughly US $1,100). Approximately four-fifths (80.58%) of the drivers had driving experience that was less than 15 years.

Measures

In both waves of collecting questionnaires, the survey items were related to the motivations (i.e., intention of eco-driving) and abilities (i.e., knowledge of eco-driving), as discussed in more detail below.

The intention of eco-driving indicated the willingness and the probability of changing the driving behaviour to save fuel. The answers for each of these items were given on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Eight items were used to measure the driver's knowledge of eco-driving, based on the following "Vehicle Fuel Consumption Guidelines" published by Taiwan's Bureau of Energy under the Ministry of Economic Affairs. Drivers had to

Table 1
Descriptive statistics of the sample.

Item		Experimental group		Control group		Total	
		Number	%	Number	%	Number	%
Gender	Male	115	99.14	105	100.00	220	99.55
	Female	1	0.86	0	0.00	1	0.45
Age	20–40	24	20.69	18	17.14	42	19.00
	41–50	48	41.38	37	35.24	85	38.46
	51–60	33	28.45	40	38.10	73	33.03
	>60	11	9.48	10	9.52	21	9.51
Education	Junior high school	32	27.59	37	35.24	69	31.22
	Senior high school	68	58.62	57	54.29	125	56.56
	University	16	13.79	11	10.47	27	12.22
Monthly salary (NT$)	20,000–25,000	8	6.90	21	20.00	29	13.12
	25,001–30,000	19	16.38	19	18.09	38	17.19
	30,001–35,000	65	56.03	40	38.10	105	47.51
	>35,000	24	20.69	25	23.81	49	22.18
Years of bus driving experience (years)	<5	49	42.24	21	20.00	70	31.67
	5–10	29	25.00	25	23.81	54	24.43
	11–15	12	10.34	20	19.05	32	14.48
	16–20	9	7.76	14	13.33	23	10.41
	>20	17	14.66	25	23.81	42	19.01

respond "know" or "do not know" with regard to each recommendation, with one point given to each positive response. Therefore, the higher the score is, the better the driver's knowledge regarding eco-driving. The questionnaires for intention and knowledge are summarised in Table 2.

Results

Effectiveness of the intervention

Table 3 shows the intention item means for the two waves of the survey and the results of the *t*-tests of mean differences of paired data over time. As shown in Table 3, there were no systematic changes over time in the control group, as expected. The drivers in the experiment group had a higher mean for all of the intention items than they did before the reward system. However, the differences were not statistically significant based on the results of a *t*-test. There was no indication that the reward system had significant effects on the drivers' intention to carry out eco-driving behaviours.

The Wave 1 results showed that drivers in both groups had good knowledge regarding eco-driving, with more than 80% knowing all of the recommendations. The analyses revealed the following knowledge items that drivers tended not to know about:

- "There is no need to warm a cold start engine by stepping on the gas while idling, but instead you should accelerate the vehicle slowly to normal temperature." Seven drivers in the experimental group (6.03%) and 12 drivers in the control group (11.43%) did not know of this.
- "Keep cruise speed in the range of 40–50 kph." Seven drivers in the experimental group (6.03%) and 5 drivers in the control group (4.76%) did not know of this.

Almost all of the drivers knew of the remaining eco-driving behaviour recommendations.

After the implementation of the reward system, three drivers (approximately 3%) in the experimental group improved their knowledge of eco-driving, specifically with regard to "there is no need to warm a cold start engine by stepping on the gas while idling, but instead you should accelerate the vehicle slowly to normal temperature," and "turn curves smoothly and steadily, and use the engine to brake when decelerating." In summary, the bus drivers already had good knowledge about eco-driving before the experiment, and the reward system did not have a significant impact in this regard.

The psychology variables of the intention and the drivers' knowledge of eco-driving did not change significantly before and after the use of the reward system. The actual fuel efficiency results from before (January–June 2011) and after (January–June 2012) the reward system showed significant improvements in the experimental group, beginning in the first month after the implementation of the reward system. Table 4 displays the results. Specifically, the first month showed a 7.6% improvement in fuel efficiency. Subsequent months also showed significant improvements that did not decline over time. The fourth to sixth month's fuel efficiency records showed year-on-year improvements of over 10.0%.

To determine if the monetary reward had the same impact on drivers with various ages, education levels, monthly salaries and years of bus driving experience, we divided drivers into different groups and compared how the reward impacted driving behaviours within the same group. We found that monetary reward still had similar impacts on fuel efficiency. Furthermore, the t-test demonstrated that the monetary reward did improve fuel efficiency for all of the drivers in the different groups (see Table 5); this conclusion is consistent with that shown in our earlier manuscript.

Factors affecting fuel efficiency change

Table 6 shows the results of a regression analysis of the fuel efficiency change with the changes in behavioural intention, knowledge and the reward system. The dependent variable was fuel efficiency change between the first and second waves. The explanatory variables included differences in intention and knowledge between the first and second waves. The

Table 2
The questionnaire of intention and knowledge.

Construct	Questionnaire
Intention	I have a strong intention to change my driving behavior to save fuel
	It is likely that I will change my driving behavior to save fuel
Knowledge of eco-driving	There is no need to warm a cold start engine by stepping on the gas while idling, but instead you should accelerate the vehicle slowly to normal temperature
	Do not accelerate quickly, but steadily
	Keep cruise speed in the range of 40–50 kph
	Use proper gear matching speed and load, and do not change gear too early or too late
	Keep the proper distance from the vehicle in front and avoid unnecessary emergency braking
	Turn curves smoothly and steadily, and use the engine to brake when decelerating
	Turn off the engine when stopping for a long period of time, instead of idling
	Keep the tire pressure within the manufacturer's recommended rang

Table 3
Statistical analysis of the intention construct.

	Experimental group			Control group		
	Mean (wave 1)	Mean (wave 2)	t (2–1)	Mean (wave 1)	Mean (wave 2)	t (2–1)
Intention (willing)	4.37	4.50	1.72	4.22	4.30	0.94
Intention (likely)	4.35	4.45	1.02	4.29	4.32	0.94

Table 4
Monthly average fuel efficiency statistics.

	Experimental group				Control group			
	Mean (km/Liter) (wave 1)	Mean (km/Liter) (wave 2)	% ((2–1)/1)	t (2–1)	Mean (km/Liter) (wave 1)	Mean (km/Liter) (wave 2)	% ((2–1)/1)	t (2–1)
January	3.63	3.93	7.63	4.72***	3.73	3.68	−1.36	−2.78**
February	3.57	4.02	11.19	6.33***	3.64	3.65	0.27	0.70
March	3.62	3.97	8.82	4.37***	3.62	3.51	−3.13	−3.11**
April	3.42	3.88	11.86	8.89***	3.33	3.24	−2.78	−4.77***
May	3.29	3.68	10.60	7.66***	3.23	3.17	−1.89	−3.11**
Jane	3.20	3.54	10.63	7.42***	3.15	3.12	−0.95	−0.81

** $p < 0.05$.
*** $p < 0.001$.

Table 5
Change fuel efficiency with various driver's characteristics.

Item		Experimental group		Control group		t-Value
		Number	Change in fuel efficiency (km/Liter)	Number	Change in fuel efficiency (km/Liter)	
Age	20–40	24	0.317	18	−0.056	5.213
	41–50	48	0.313	37	−0.053	8.034
	51–60	33	0.314	40	−0.058	5.722
	>60	11	0.216	10	−0.086	4.030
Education	Junior high school	32	0.302	37	−0.042	5.831
	Senior high school	68	0.305	57	−0.076	9.452
	University	16	0.310	11	−0.026	3.421
Monthly salary (NT$)	20,000–25,000	8	0.309	21	−0.007	4.949
	25,001–30,000	19	0.523	19	−0.093	6.634
	30,001–35,000	65	0.272	40	−0.054	7.023
	>35,000	24	0.220	25	−0.033	5.396
Years of bus driving experience (years)	<5	49	0.347	21	−0.044	5.133
	5–10	29	0.303	25	−0.067	7.095
	10–15	12	0.385	20	−0.068	4.725
	16–20	9	0.209	14	−0.057	4.679
	>20	17	0.181	25	−0.055	4.454

Table 6
Estimated results for the regression model.

Independent	Estimates		t-Value
Constant	β_0	−.067	−2.895
Change in intention	β_1	0.022	1.209
Change in knowledge	β_2	0.061	1.371
Reward intervention (dummy)	β_3	0.363	11.645***
R^2		0.39	

*** $p < 0.001$.

experimental group dummy (experimental group: 1, control group: 0) was also included. As seen in Table 6, changes in the behavioural intention to adopt eco-driving practices were positively but non-significantly correlated with changes in fuel efficiency ($\beta_1 = 0.022$, t-value = 1.209). Additionally, the change in knowledge had non-significant positive effects on the change in fuel efficiency ($\beta_2 = 0.061$, t-value = 1.371). Hence, the possible effects of the reward intervention on the change

in fuel efficiency through changes in intention and knowledge can be ruled out. However, in terms of the change in fuel efficiency, the most powerful predicator was experimental intervention ($\beta_3 = 0.363$, t-value = 11.645). Therefore, offering the reward system did significantly increase fuel efficiency.

Discussion

Bus companies consume millions of litres of fuel every year, and their fuel costs often exceed millions of US dollars. Therefore, these companies have an obvious interest in reducing their fuel consumption. Numerous studies have examined the impact of eco-driving training courses on fuel consumption. The results indicated that training courses can yield significant improvements in fuel economy. However, this affect was gradually lost in the months after the course. Some bus companies are using monetary rewards to encourage eco-driving behaviour and cut fuel use, although the effectiveness of such intervention has not been studied. To address this gap in the literature, this study used experimental methods to examine the effects that a financial reward for greater fuel efficiency has on driver behaviour and actual fuel efficiency. The empirical analysis showed that personal characteristics did not have a significant effect on fuel efficiency. In contrast, the eco-driving reward, an extrinsic condition, did have a significant effect on fuel efficiency. The results for the average fuel consumption efficiency for the buses before and after the reward system was introduced showed an improvement of more than 10% and thus a reduction in carbon emissions. Specifically, the first month showed a significant improvement in fuel efficiency and did not decline over time.

An eco-driving reward system is an effective strategy for improving fuel efficiency and lowering the operating costs of bus companies. The average fuel efficiency of all of the buses in the experimental group company changed from 3.3 km/l to 3.62 km/l after the intervention of the reward system. The estimated amount of total fuel saved was 645,706 litres, and the total cost saved was US$ 732,000. The eco-driving reward system had significant benefits to the bus company when compared to the amount of monetary rewards given (US$ 108,000) and should be more widely adopted within the industry.

It should be noted that the execution of an eco-driving program requires the establishment of fuel consumption standards that the drivers are then asked to achieve. However, due to the multitude of factors that affect fuel consumption (e.g., vehicle model, such as make, year and engine displacement size; and route characteristics, such as passenger load, running speed and number of traffic signals stops), it is difficult to establish such objective standards. This can create a significant problem for bus companies as they attempt to convince drivers that their fuel conservation targets are fair and realistic. It is recommended that further research should be conducted to investigate a fuel consumption standard that is reasonable for each operator's bus fleet. Furthermore, certain managerial theories have argued that incentives to improve employee performance include not only cash rewards but other factors (e.g., status, job security, salary, work conditions and company policies). The impact of these factors on eco-driving can be investigated in future research.

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