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Using incentives as traffic management tool: empirical results of the “peak avoidance” experiment

ABSTRACT: Although positive incentives have been successfully applied in various domains to influence behavior, they have received limited attention in transportation. This paper reports on the Dutch ‘Spitsmijden’ (‘Peak Avoidance’) project, in which travelers received positive incentives if they avoided travelling in the peak by car. Incentives could be financial (3 to 7 EURO per day) or credits to earn a smartphone at the end of the experiment. Travelers’ responses were measured using electronic detection equipment and travel diaries. The results of the study indicate that positive incentives are able to reduce the amount of peak traffic of the participants by about 60%. Travelers mainly responded to the incentives by shifting their car trips to the periods before and after the peak period. Although the experiment was intended to achieve a structural change in travel behavior, we observed that travelers returned to the peak period when the incentives ended.

KEYWORDS:

1. INTRODUCTION

Increasing car ownership and car use levels lead to high external costs of our transportation systems in terms of congestion and pollution. Among the policies that have been proposed to relieve these negative externalities, road pricing is increasingly considered a promising alternative. Road pricing is based on the principle that by internalizing the external costs of car traffic, an economically more efficient system is obtained. This will increase the welfare of all road users, assuming that the tolls that are levied are in some way returned to the road users (Rouwendal and Verhoef, 2006). In the ideal case, prices are set such that they equal the marginal costs of a trip, including the marginal external costs. In practice, this will imply that the use of the road system is charged higher at congested periods and congested locations, so that use of the road system at those times/places is discouraged and road users are encouraged to use alternative modes, routes or times. It is these behavioral responses that lead to an increased efficiency of the transportation system (Bonsall *et al*., 2007).

In practice, many operational decisions and specific circumstances will influence the behavioral responses to road pricing schemes and their efficiency. First, the behavioral responses to road pricing schemes depend on operational decisions regarding the toll level and especially the differentiation. If tolls are only differentiated by place, responses will include route changes, mode changes and destination changes. If tolls are also differentiated by time, the timing of trips may be affected, in the sense that trips will be planned before or after the peak period. The response to price policies will also depend on the availability of alternatives, such as good public transport alternatives or flexible work hours.

With respect to behavioral options, responses may extend to changes in activity patterns, life styles and work and residential locations (Tillema *et al*., 2010; Arentze and Timmermans, 2007), leading to long-term effects that are different from immediate effects. Finally, it is noted that travelers’ characteristics play an important role in their response to road pricing, the key characteristic being income. The higher one’s income, the less sensitive one is to the toll and the less likely to change one’s behavior.

To date, road-pricing measures have been implemented in various places throughout the world (see Bonsall *et al*. (2006) for an overview). In most cases, road pricing has been found to be an effective tool to reduce congestion and achieve

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a more efficient use of the transportation system. At the same time, it is noted that the implementation of road pricing is not without controversy. For instance, in the Netherlands, discussions on such issues as social equity (stemming from the fact that individuals with a higher value-of-time (VOT) receive larger benefits from road pricing than those with a lower VOT), public acceptance and technological feasibility have to date prevented the implementation of road pricing, although cost-benefit analyses typically conclude that road pricing would lead to positive societal benefits (*e.g.*, CPB, 2005). In the context of this discussion, studies are undertaken to further explore options for implementing advanced pricing policies and investigate their consequences in terms of accessibility, social effects and public acceptance (see, for example, various contributions in Verhoef *et al.*, 2008).

An idea that has recently been put forward (Ettema and Verhoef., 2006; Knockaert *et al.*, 2007) is to investigate whether the behavioral change that is envisaged in road pricing measures, can also been achieved by giving positive incentives to road users. The idea of using positive incentives to achieve behavioral change is relatively new to transportation planning and traffic management, but has been applied in other domains frequently. Sansgiry *et al.* (2006) describe the effect of positive incentives on student performance on examinations. They find that positive incentives are effective tools to increase student performance, but also conclude that the specific form of incentive has a large impact on the effectiveness. Guyll *et al.* (2003) describe the effect of positive incentives on participation rates of a preventive intervention study, which involves repeated interviewing rounds, posing a heavy burden on families. They found that a 100$ incentive positively contributed to a higher participation rate. Church (1993) reports on the effectiveness of monetary and non-monetary positive incentives in mail survey response rates. He finds that both monetary and non-monetary positive incentives improve response rates, but that monetary incentives are more effective. Also, an incentive is found to be more effective when it is given initially, instead of conditional upon returning the survey. This is confirmed by a study by Willimack et al. (1995), who found that a small incentive (a writing pen) increases the willingness to participate in a face-to-face interview. Other studies (Moses and Clark, 2004; Porter and Whitcomb, 2004) find no effects of a lottery incentive on the response rate in a mail back survey. With respect to the value of the incentive, Geller (2001) suggests that a small incentive is more effective than a large incentive, since it causes individuals to develop internal motivation for the behavioral change. Harland *et al.* (1999), report on a project where inhabitants of a disadvantaged area in Newcastle took part in a program to promote physical activity, using varying strategies. Apart from brief or intensive motivational interviewing, some participants received financial positive incentives whereas others did not. It is found that financial incentives contribute to a change in behavior, but only when combined with intensive motivational interviewing. The behavioral change (an increase in physical activity) was, however, not sustained over a longer period.

To summarize, the literature suggests that positive incentives can be applied to stimulate a variety of behaviors, and in some cases also establish behavioral change. This suggests that positive incentives may also work to change travel behavior. However, there are also aspects of travel behavior that are fundamentally different. For instance, travel behavior in the context of daily congestion typically involves repeated behavior, which differs from unique events such as returning a survey or passing an examination. Transport policies aim at structurally changing travel behavior, making the longer-term effect of incentives more of an issue. Both the behavioral effect under longer periods of giving incentives and the behavior after the incentive has stopped have received limited attention in the literature but are crucial to the assessment of incentive strategies as traffic management tools. Haq *et al.* (2008), applied incentives, such a free bus pass, cycle/walk maps and a pedometer, in personal social marketing, aimed at achieving more sustainable travel behavior. They found mixed effects of the reward, and also found that environmentally friendly behavior was not sustained after the reward program. However, the study by Haq *et al.* (2004) used only specific types of incentives, which do not include financial incentives or luxury items, as in the current study.

Another issue raised when considering the use of positive incentives as a transport policy option is to what extent the effect of a financial incentive and a toll of the same size will be symmetrical. Micro-economic theory, which has been dominant in transportation research, typically assumes uniform elasticities of price increases and decreases. On the other hand, literature in psychology (Kahnemann and Tversky, 1979; Schwanen and Ettema, 2007) has for several decades pointed at the difference in valuation of gains and losses. This research has usually taken place in the context of so called risky choices, in which individuals have to choose between for instance a small probability of a large financial gain/loss and a high probability of a small financial gain/loss. Controlled experiments indicate not only that distortions exist in the valuation of probabilities, but also that losses loom larger than gains of the same size. However, the effect of potential gains or losses on actual behavior has not been investigated in the context of daily travel decision-making.

In order to explore the option of achieving behavioral change using positive incentives and investigate some of the above issues the "SpitsMijden" (Peak Avoidance) project was launched. In this project, the use of positive incentives was tested as a means to stimulate behavioral change on a congested highway in The Netherlands. The objectives of the project were:

- to gain first insights in the effectiveness of incentive strategies with different types and sizes of rewards, and draw conclusions regarding the sustainability of the measure. In this respect the emphasis is on the primary responses of participants. Since the scale of the project is insufficient to bring about substantive changes in traffic volumes, the effects on congestion and travel speeds are outside the scope of this paper;
- to test technological and administrative procedures needed to implement reward strategies
- to test the impact of various situational contexts on the effect of the reward strategy, such as to be able to determine particular segments to target with these strategies.

With respect to the latter point, Garling and Fujii (2006) note that situational constraints may limit individuals' behavioral response to policies. Such constraints may be related to household responsibilities, work organization and availability of information.

This paper describes the organization and outcomes of the Peak Avoidance test, focusing on the behavioral issues mentioned in the above (for technical and organizational conclusions: see Knockaert *et al.*, 2007). To this end, the paper is organized as follows. Section 2 describes the organization of the test, including details of the incentive strategies that were used. Section 3 discusses the results on an aggregated level, emphasizing the effect of various incentive strategies on modal and temporal shifts, and also discussing the sustainability of the effects. Section 4 discusses the impact of situational variables on the behavioral change caused by the positive incentives. In section 5, conclusions are drawn regarding the experiment and directions for future research are charted.

2. ORGANIZATION OF THE SPITSMIJDEN TEST

Timing and location

The test took place in September-November 2006 on the A12 motorway from Zoetermeer to The Hague (see Figure 1). This trajectory is heavily congested due to the large number of commuters travelling to The Hague in the morning peak. Traffic counts indicate that about 6000 car drivers travel between Zoetermeer and The Hague in the morning peak.

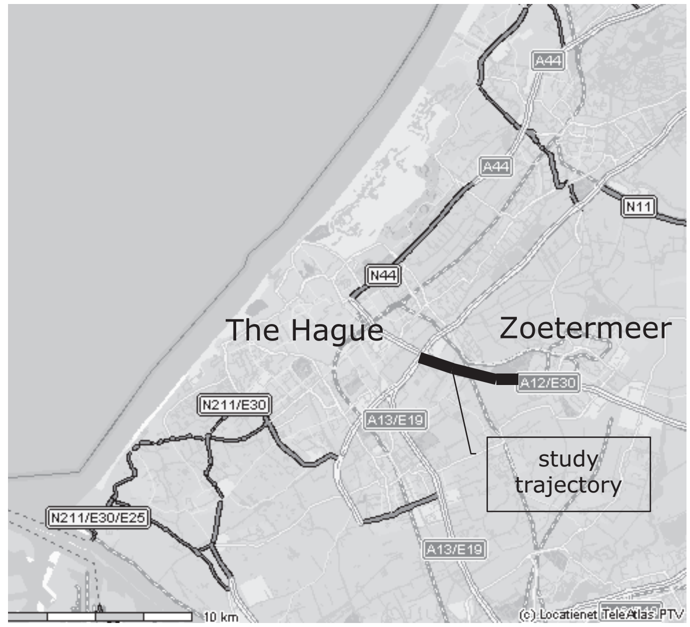

Figure1. The Study Trajectory.

340 daily commuters between Zoetermeer and The Hague were recruited to participate in the test. The recruitment took place using number plate recognition. Car owners whose car was detected on the A12 at least three times per week were approached to participate in the test.

Although participants were frequent car drivers, the availability of public transport is relevant as an option to avoid the morning peak. The historical public transport supply on the Zoetermeer-The Hague corridor mainly relies on two heavy-rail systems. The first is a local rail loop (Zoetermeer Stadslijn) that serves all quarters of Zoetermeer north of the A12 motorway and connects them to The Hague. The second is the mainline rail connection between Gouda and The Hague, which serves two stations in Zoetermeer (both are adjacent to the A12 motorway).

The original reason to schedule the trial for the autumn of 2006 was the plan to convert the local heavy-rail loop into light rail operation and to link it to the existing light rail system in The Hague in the summer of 2006. At the start of the trial it turned out that the new light rail system was not operational, and that as a result the local rail loop was replaced by a bus service, which was overcrowded in the peak periods. The intended light rail line went into service during the Spitsmijden project, but was taken out of service within a few weeks due to technical problems. It was then replaced by the previous inferior bus service. To summarize, availability of public transport to travel between Zoetermeer and The Hague has been suboptimal, and has relied mostly on the heavy rail mainline connection, which is overcrowded in the peak period. Especially local transport in Zoetermeer, connecting the residential areas to the mainline stations has been of low quality.

Incentive strategies

The trial consists of two reward programs in which participants take part for 10 weeks. In each program, participants can earn rewards if they do not travel by car between Zoetermeer and The Hague in the morning peak, defined as the period 7:30-9:30. That is to say, they receive an incentive if they travel:

- By car before the peak
- By car after the peak
- By public transport, bicycle or carpool
- Or if they do not travel (e.g. if they work at home).

It should be noted that avoiding the peak is defined relative to the usual behavior. In particular, someone who usually travels in the peak four times per week can receive a maximum of four incentives per week. The definition of 'usual behavior' was based on measurements preceding the actual test period.

In the first reward strategy, participants could earn a fixed amount of money each day they do not travel by car in the peak. Different monetary rewards were applied during the 10 week test period.

- 3 euro to avoid the 7:30–9:30 peak period (three weeks)
- 7 euro to avoid the 7:30–9:30 peak period (four weeks)
- 7 euro if the full morning commute 8:00–9:00 is avoided; 3 euro when travelling in the shoulders of the peak period (7:30-8:00; 9:00-9:30) (three weeks)

Each participant was confronted with each of three variants, however the order in which they occurred differed.

In the second reward strategy, participants earned 1 credit, each day they do not travel by car in the peak. If they earned sufficient credits (60% of the maximum) they earned a Yeti-Smartphone. The Yeti-Smartphone is a navigation system guiding car drivers to their destination using spoken instructions. The Yeti provides real time traffic information and also provides standard functionalities of a PDA such as agenda, email, Word, Excel, Notes, Internet and telephone. The retail price of the Yeti-Smartphone is about 600 €. Participants receive the Yeti at the beginning of the test, so that they can gain experience with the services offered by the Yeti. Consequently, their behavior may be affected by the incentive of keeping the Yeti after the test, but also by the travel information provided by the Yeti. To test both effects, two regimes were defined:

- participants received travel time information through the Yeti, but no rewards are given (5 weeks)
- participants received travel time information through the Yeti, and rewards are given upon avoiding the peak (5 weeks)

Each participant in this strategy was confronted with both variants, with the order being randomly assigned.

When recruited, participants could state their preference for one of the two strategies. Eventually, participants were assigned to a strategy according to their preference, leading to 232 participants signing up for the monetary reward and 108 choosing the Yeti reward. It should be noted that rewards were given for a reduction of car trips in the peak relative to the base situation. For instance, someone travelling by car in the peak three times per week can earn up to three rewards per week. The rewards were determined relative to a two week pre-measurement preceding the actual reward period (see later).

Detection and data

During the experiment, participants' car use is recorded by a detection system that covers all relevant routes between Zoetermeer and The Hague. Via a transponder that is installed in all cars in participants' households, it is recorded whether participants travel by car in the peak or outside the peak. As a backup system, license plate recognition cameras were installed on all relevant routes. Both the transponder system and the cameras showed a very satisfactory level of detection. Whereas the detection rate of the cameras ranged from 94 to 98%, the detection rate of the transponders was as high as 99.8% (see Knockaert *et al.* (2007) for details). If a participant is not detected on a particular day, the reason for this (e.g. using other modes, working at home, taking a day off) is recorded in a diary (see later).

In addition to the car detection data, various other data were collected that are relevant to this paper. Upon recruitment, respondents provided information about their home and work location, flexibility of the work organization, household obligations, availability of travel modes and use of traffic information. In addition, common socio-demographic characteristics were recorded. During the test period, participants filled out a diary, in which they registered whether a car trip was made and at what time. If no car trip was made, the reason for this (other mode, non-working day, etc) was entered. Following the test period, participants filled out an evaluation questionnaire, including questions about their experiences with the test and reasons for diversions from the planned behavior. All data on participants' car use, alternative behaviors, socio-demographics and situational constraints were collected in a central database that was used

Table 1. Sample characteristics

		Number	Percentage
Gender	Men	220	64,7%
	Women	120	35,3%
Age	< 24	14	4,1%
	25-34	68	20,0%
	35-49	170	50,0%
	>49	88	25,9%
Household type	Single	44	12,9%
	couple without children	82	24,1%
	couple with children	190	55,9%
	single parent	17	5,0%
	Other	7	2,1%
Education level	High school	34	10,0%
	Middle professional	17	5,0%
	Middle professional	95	27,9%
	Higher professional/ university	194	57,1%
Commute frequency	3 times/week	41	12,1%
	4 times/week	88	25,9%
	5 times/week	211	62,1%

to administer the payment of rewards and serves as a base for further analyses. For our analyses it is important to note that various data sources are combined to create the response variable. First, the transponder and camera data are used to establish whether there a car trip is made and in what period. Second, (if no car trip is observed) the log filled out by participant is used to determine whether a trip by another mode was made or one worked from home. Thus, we have data available for each working day, regarding the choice made with respect to mode choice and (in case of car) timing of the trip. These daily observations are the basis of our analyses.

The actual test period started at 2 October 2006 and ended 8 December 2006. Participants' behavior was recorded using the detection system and the logs two weeks before and one week after the actual test period. These data serve as a reference against which to interpret the outcomes of the test.

Since the test took place on a trajectory of the Dutch motorway system, detailed information is also available from the continuous monitoring system of the Ministry of Transportation regarding traffic intensities and speeds. These could in principle be used to measure the effect of reward strategies on the total volume of traffic. However, given the relatively small number of participants, this effect is negligible here. Therefore, the aggregate data about traffic density is not further used in this study.

3. SAMPLE DESCRIPTION

The sample characteristics are summarized in Table 1. The sample consists of 67% males and 33% females. About half of the participants is between 35 and 49 years old. About 25% is younger than 25, while the same share is older than 49. The majority of the participants holds a higher professional education or university degree. Most likely, this is related to the fact that higher qualified jobs offer more opportunity to independently schedule ones work activities. 56% of the participants are married or cohabitate with children while 24% is a couple without children, suggesting that for many participants, household obligations may affect their response to the reward strategies.

With respect to current travel behavior, 62% of the participants commutes five times per week (or more) to The Hague, using the A12 motorway. 26% commutes 4 times per week. 84% of the participants commutes only by car, including both car trips inside and outside the peak period. The other 16% combines using the car with one or more other options, such as using Park&Ride (6.4% of the participants), motor (2.4%), train (4.7%), bus (1.8%) or bike (6.2%). 34% regards public transport as a serious travel option, while the bike is regarded an option by 18%.

Average commute time including congestion is 36 minutes according to participants. The average reported free flow time is 20 minutes, implying an average delay due to congestion of 16 minutes. A vast majority of 90% of the participants

Table 2. Work start times

Work start time	Number	Percentage
Before 6:30	6	2%
6:30-7:30	15	4%
7:30-8:30	192	56%
8:30-9:30	115	34%
After 9:30	11	3%
Unknown	1	0%
Total	**340**	

Table 3. Constraints from Work and Household Organization

Opportunity for later work start	**Number**	**Percentage**
Cannot start later	146	43%
Can start max. 30 minutes later	43	13%
Can start 30-60 minutes later	86	25%
Can start 60-120 minutes later	54	16%
Can start more than 120 minutes later	11	3%
Unknown	1	0%
Total	**340**	
Situation upon early arrival at work	**Number**	**Percentage**
Can directly start working	268	79%
Cannot start yet, but can make preparations	32	9%
I have to wait until a specific time	11	3%
I have to wait for colleagues before I can start	7	2%
I cannot yet enter the building	8	2%
Other	14	4%
Total	**340**	
Household circumstances affecting departure time choice (multiple options)	**Number**	**Percentage**
Child care	100	29.4%
Having breakfast with family	33	9.7%
Have to drop off children at school	66	19.4%
Have to drop off partner	20	5.9%
Carpool arrangements	8	2.4%
Business appointment	37	10.9%
Other	28	8.2%
None of the above	157	46.2%

usually arrives at the work place between 7:30 and 9:30h (the morning peak as defined in this study) (Table 2). 57% of the participants is allowed to start working later than the usual work start time (Table 3). Mostly, a delay up to 60 minutes is allowed.

When arriving early at the work place, the majority of participants (79%) can start working right away (Table 3). 9% can start preparations, suggesting that an early departure from home in order to avoid the peak will be an option for many.

Apart from work flexibility, the flexibility of household activities plays a role in participants' responses. In total, 54% of the participants faces one or more constraints, stemming from household obligations that avoid early or late departure from home. Table 3 suggests that especially child care and dropping off children at school prohibit an early or late departure. Finally, 41% of the participants uses traffic information (regarding road traffic) at least once a week. This share is the same for participants who chose the financial reward (40%) and those who chose the Yeti (43%). Only 3% uses traffic information regarding public transport once a week or more.

4. MODAL AND TEMPORAL SHIFTS

As noted previously, commute behavior was recorded on a daily basis during various reward variants, as well as in the periods preceding and following the reward period. This section will present and discuss the results of the reward strategies on an aggregate level. This is done by analyzing the aggregate distribution across travel modes and travel times in various reward variants and comparing these distributions with those in the reference periods before and after the trial. The results are discussed for the financial reward scheme and the yeti-reward scheme. Note that choices made on a working day are the unit of analysis. Since participants took part in each condition for multiple weeks, the number of observations exceeds the number of participants in each scheme.

4.1. Financial incentive

Table 4 indicates the transport methods and travel times at pre-measurement, for the three reward variants and at post-measurement. It gives the distribution over all commutes (or telework days) made during the period and/or for the variant. In the periods without rewards (pre- and post-measurement), 47-50% of the participants travelled by car during the rush-hour. This indicates that a large proportion of the participants already travelled outside of rush-hour before the reward scheme was introduced. This is partly caused by the fact that we used a broader definition of rush-hour during the recruitment phase. In addition, the evaluation questionnaire revealed that about a quarter of the participants

Table 4. Distribution of commute trips across times and modes in various financial incentive schemes

	Premeasurement	3 Euro	Variable incentive	7 euro	Postmeasurement
By car before 7:30	20.1%	33.0%	37.8%	38.5%	20.7%
By car 7:30-8:00	17.8%	8.9%	7.4%	6.0%	19.1%
By car 8:00-9:00	27.4%	15.1%	9.9%	10.9%	24.3%
By car 9:00-9:30	4.8%	2.4%	2.4%	2.2%	3.8%
By car after 9:30	10.3%	16.0%	15.9%	15.1%	12.0%
Other car in household	1.0%	0.7%	0.4%	0.4%	1.0%
Other car outside household	0.1%	0.6%	0.1%	0.2%	0.5%
Passenger in carpool	0.8%	1.9%	1.8%	2.2%	1.4%
Public transport	3.9%	9.5%	12.0%	11.4%	6.1%
Bicycle	5.2%	4.1%	3.2%	3.5%	1.6%
Other mode	2.8%	2.1%	3.2%	2.2%	2.0%
Telecommuting	2.6%	3.1%	3.2%	3.9%	2.5%
Other work location	3.2%	2.7%	2.8%	3.4%	4.8%

began practicing adjusting their driving behavior during the preliminary measurements. Note that this, if ignored, will lead to a downward bias in the estimated behavioral effects of rewarding. For future applications, this suggests that the reference behavior of participants should be recorded while they are unaware of the upcoming reward measure. The percentage car travelers in the peak shrank to 26% with a € 3 reward and to 19-20% with a € 7 or variable reward. Thus, the effect of incentives on car travel during rush-hour was very significant. Reducing the share of in-peak car travel from 50% to 20% effectively implies a reduction of the number of car trips in the peak by 60%. Avoiding the rush-hour was primarily realized by travelling by car outside of the rush-hour period. The proportion of car trips before 07:30 increased from 20% to 33-39%. The proportion of car trips after 09:30 increased from 10% to 15-16%. Total car use over all time periods decreased from 80% to 73-75%.

After the end of the reward phase, car use during the rush-hour returned to premeasurement levels. This suggests that behavior stimulated by rewards is not continued when the reward is withdrawn. Apparently, the participants do not value the alternative behavior stimulated by the reward enough to continue using the options they had chosen during the trial, such as travelling outside of the rush-hour or using public transport. Consistent with this, the measures taken to enable participation in the Spitsmijden trial, such as adjustments in work times or family obligations, may have been taken only for the duration of the reward period, while respondents saw no reason to prolong these measures. One might conclude from this that, apparently, experimenting with alternative behavior did not produce updated perceptions on the relative attractiveness of the various travel options.

The decrease in car use was primarily attained by increased public transport use (from 4% in the preliminary measurements to 9.5-12% during the reward phase). An interesting detail is that public transport use was slightly higher during the postmeasurement period than during the preliminary measurements, while the reverse holds for cycling. Changes in weather and season over the course of the experiment may have played a role here. The number of teleworkers increased slightly during the trial.

A comparison of the different reward variants shows that a reward of € 3 already accounts for the largest part of the mode and time shift (i.e. a reduction in travel during rush-hour from 50% to 26%). Variable rewards and a € 7 reward lead to an additional reduction to 19%. Variable rewards lead to a distribution over alternative transport methods and times that is almost identical to what is achieved with a € 7 reward. Apparently, the participants saw little point in (or possibilities for) exploiting the added possibility of a smaller trip time adjustment in exchange for a smaller reward..

With respect to the incentives earned by participants, it turns out that a majority of them earned at least 85% of the maximum amount of incentives. This indicates that this group avoids the car trip in the peak very consistently. A much smaller group (about 10% of the participant) avoids the peak less than 50% of the times.

4.2. Yeti-credits as an incentive

In the Yeti variant, three situations could apply for a respondent during the trial:

Table 5. Distribution of commute trips across times and modes in various Yeti incentive schemes

	Premeasurement	Incentive relevant	Incentive non relevant	Only traffic information	Postmeasurement
By car before 7:30	21,0%	30,9%	24,9%	21,9%	21,3%
By car 7:30-8:00	11,6%	4,8%	8,9%	10,0%	10,4%
By car 8:00-9:00	20,8%	6,9%	16,3%	16,6%	24,2%
By car 9:00-9:30	10,4%	3,3%	4,4%	5,8%	7,0%
By car after 9:30	17,1%	25,3%	20,1%	21,3%	17,2%
Other car in household	1,5%	0,4%	0,2%	1,4%	0,2%
Other car outside household	0,4%	0,1%	0,6%	0,1%	0,5%
Passenger in carpool	1,1%	3,0%	2,4%	2,2%	2,0%
Public transport	5,8%	13,2%	12,9%	9,0%	6,6%
Bicycle	2,2%	0,8%	0,8%	1,7%	0,7%
Other mode	1,9%	2,5%	2,0%	2,5%	2,5%
Telecommuting	2,6%	5,1%	4,0%	3,8%	2,9%
Other work location	3,6%	3,7%	2,4%	3,8%	4,5%

1. For the duration of five weeks the participants had to avoid enough rush-hours to earn sufficient credits to be allowed to retain the Yeti. They also received traffic information on the Yeti;
2. For the duration of five weeks the participants only received traffic information;
3. As in situation 1, but the incentive was no longer relevant: the participant either already had accumulated sufficient credits to keep the Yeti, or had accumulated so few credits that the critical limit could no longer be reached (he/she still received traffic information on the Yeti).

The distribution of all commutes across different periods and modes in different reward variants is displayed in Table 5. The percentage of car trips during the rush-hour shrank from 43% to 15% due to the prospect of being rewarded with a Yeti. This decrease is comparable with the reduction due to a monetary reward of € 7 or the variable reward. As in the monetary variant, this reduction was largely realized by an increase in trips before 07:30 (from 21% to 31%) and after 09:30 (from 17% to 25%). Total car use over all periods declined from 81% to 71%.

As with the monetary variants, this decrease was realized by an increase in the use of public transport (from 6% to 13%), with the bicycle playing no significant role. Remarkably, in this reward variant more participants chose teleworking than in the monetary variants. As in the monetary variants, post-measurements indicated that the number of car trips during the rush-hour had returned to the level of the preliminary measurement. An interesting phenomenon occurred when participants received traffic information on the Yeti but could not earn a reward. This was the case when the reward was no longer relevant as the Yeti had already been earned or could no longer be earned, or during a period without a reward. In these cases, the number of car trips during the rush-hour was significantly lower than during the pre- and post-measurements.

One possible explanation is that the traffic information enabled the participants to avoid traffic due to heavy congestion by delaying or advancing their departure time or choosing another form of transport. But this could not explain the return to pre-measurement levels in the post-measurement period. A second possible explanation is that the participants may not have been completely familiar with the relevance to their reward of avoiding traffic and therefore may have adjusted their behavior when it was not strictly necessary to do so. A third possibility is that the arrangements made to avoid the peak (e.g. changed work times) were made for the entire period of the trial and therefore continued during the periods with no reward apart from the traffic information.

With respect to the credits earned by participants, Figure 2 suggests that most of the participants earn 90 to 129% of the credits they need to obtain the Yeti. This suggests that their change in behavior is aimed at obtaining the Yeti, and that they return to their usual behavior once sufficient credits are obtained. This would confirm the earlier finding that participants are primarily motivated by the incentive, when changing their behavior. However, a small fraction earned more than 150% of the needed credits. This group is probably more motivated to maintain the peak avoiding behavior.

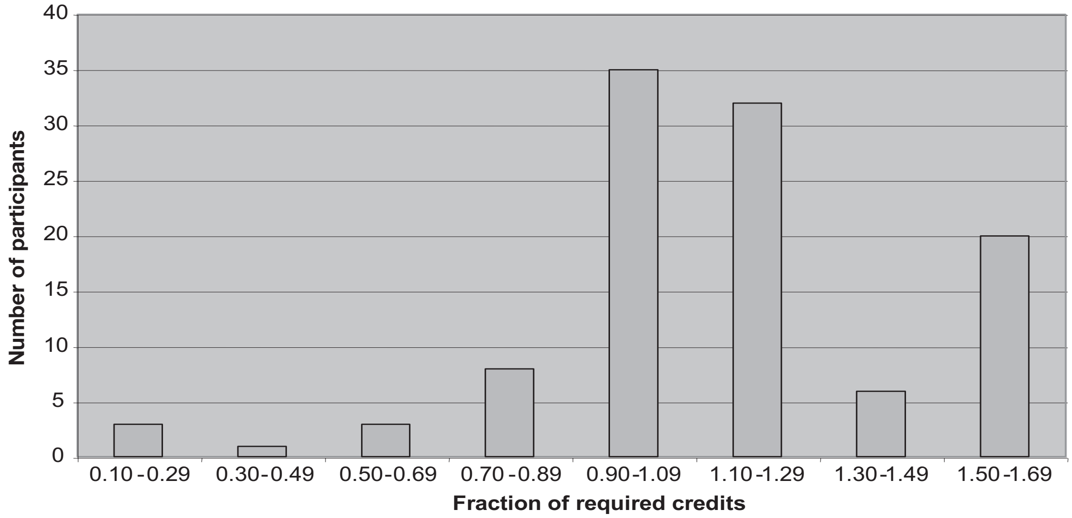

Figure 2. Yeti credit earnings as a fraction of the required limit.

5. SITUATIONAL EFFECTS

As mentioned in section 1, the individual situational context may affect the individuals' opportunities for behavioral change. In particular, it can be hypothesized that factors such as constraints stemming from family or work situation and the availability of alternatives affect the response to incentives. To investigate this, we studied how groups of participants differ in their degree of behavioral adjustment. The groups were identified based on the following criteria:

- Car ownership;
- Gender;
- Single parenthood;
- Availability of public transport;
- Ability to start work earlier;
- Ability to start work later;
- Ability to depart earlier due to family circumstances;
- Regular use of traffic information before the trial;
- Level of education;
- Income;
- Age.

To analyze whether these factors influence the response to incentives, logistic regression models for possible behavioral reactions (such as driving less in traffic, more often before or after the rush-hour, more public transport or working from home) were estimated. The dependent variable in these models is a dummy variable indicating whether or not an increase in the relative frequency (expressed as a percentage of all morning peaks) of the particular behavior is observed during the duration of a particular incentive. The dummy is calculated for each individual. When estimating the models, we followed a sequential procedure where only those variables were included that were significant at (α =0.05).

5.1. Situational effects in the monetary variant

The results of the logistic regressions are listed in Table 6. This table shows that car ownership has an effect on the way in which participants react to a monetary reward. A household that owns two or more cars will be less likely to reduce the number of car trips during the rush-hour. Apparently, the presence of two cars indicates a greater dependency on automobility or a greater preference for car use, resulting in a lower motivation to adjust behavior. Ownership of two or more cars also reduces the likelihood of driving before or after the rush-hour. Teleworking, however, is more likely among this group. A potential explanation is that workers with high car availability have more mobile lifestyles, and are more used to work in a flexible way from various locations, including the home.

The availability of a public transport alternative has a clear effect on the participants' reactions. If a public transport alternative is available, the percentage choosing to travel by public transport is greater and the likelihood of avoiding the rush-hour increases. Here, the causality may of course be reversed: if two individuals have objectively the same public transport connection, the person who is more inclined to use it may also judge its availability as "better".

Flexible work times also have a clear effect on the reactions observed, although the findings for this group of char-

Table 6. Logistic regression models of responses to incentives

	Travel less in peak by car	Travel more before the peak by car	Travel more after the peak by car	Travel more by public transport	Work more at home
Monetary incentive					
Variables					
Constant	-0.12	0.17	-0.78	-2.04	-2.81
Household has 2 or more cars	-0.59	-0.53	-0.34		0.65
PT alternative available	0.65			1.66	
Can start working earlier	1.04				
Can start working later			0.83		
Can leave home earlier		0.54			
Can leave home later					0.52
Income > 4500€/month				0.71	
Single parent		-1.56			
Highly educated					0.96
Age > 51 years				-0.65	
Regular user of traffic information	0.48				
*-2*LL*	737.105	875.569	846.734	622.028	505.802
Nagelkerke R^2	0.089	0.062	0.044	0.188	0.069
Yeti credits incentive					
Variables					
Constant	-0.22	-1.77	-0.87	-1.24	0.05
PT alternative available				1.63	
Can start working earlier					-1.66
Can start working later			0.84	-0.80	1.11
Can leave home later					0.77
Income > 4500€/month	0.66	0.91		-1.35	
Highly educated	0.68	0.73			1.06
Age 36-50 years					1.10
Male	1.00				
Credits not relevant			-0.58		-0.99
Yeti only used for traffic information	-0.62				
*-2*LL*	327.345	333.570	364.480	255.907	219.370
Nagelkerke R^2	0.132	0.146	0.064	0.218	0.226

Only variables significant at (α = 0.05 are included in the models)

acteristics are somewhat tautological. Being able to start work earlier leads to a greater probability of avoiding peak traffic, but not directly to a larger probability of actually driving before the rush-hour. Being able to leave home earlier due to a lack of family obligations, however, does lead to a larger probability of avoiding traffic by leaving earlier. Being able to start work later leads to a significant higher probability of leaving for work after the rush-hour. Finally, participants who could leave home later due to their family circumstances are more likely to work from home.

With respect to personal characteristics, we find that participants with a high income are more likely to use public transport as an alternative. A potential explanation is associated with the location of highly qualified jobs. Various government agencies and large firms are located in the centre of The Hague and therefore have a good accessibility by public transport. The analysis further shows that single parents rarely consider leaving for work earlier as an alternative. This may be explained by childcare obligations, which keep them from leaving home earlier. Well-educated participants were more likely to choose to work from home, probably since they are more flexible in organizing their work in time and space. Older participants were less likely to take public transport.

We also found that participants who regularly consulted traffic information were more likely to show a decrease in trips during the rush-hour. The use of traffic information possibly enabled them to better avoid traffic caused by unexpected congestion. Also, this group may be more flexible in their behavioral adjustments since they are used to react to information regarding unexpected travel circumstances. Our analyses show that the amount of reward has no significant influence on the probability of displaying a certain reaction. It should be noted though that the amount of reward probably has an effect on the frequency of behavioral adjustment, as suggested by Table 4.

5.2. Situational effects in the Yeti variant

In a similar vein, the effects of incentives in the Yeti variant were analyzed. This analysis took into consideration the two reward conditions for the Yeti variant, namely:

- *Yeti smartphone:* the participants could save up to keep the Yeti at the end of the trial by avoiding traffic. They also received traffic information on the Yeti;
- *Traffic information:* the participants received traffic information on the Yeti, but could not save up to keep it at the end of the trial.

Some of the differences between the various groups of participants shown by the Yeti participants were comparable to those seen in the monetary variant. Participants who had a public transport alternative chose to use it more often, but this did not lead to a reduction in the number of trips made during the rush-hour. Employees who were able to begin work later appeared more willing to travel after rush-hour. This emphasizes the importance of the work organization for the reaction to reward arrangements. These participants travelled less by public transport and were more likely to see teleworking as an option.

Participants who were able to begin work earlier were less likely to choose to work from home. Participants who were able to leave home later due to family circumstances were also more likely to choose to work from home. Furthermore, well-educated participants were more likely to avoid peak traffic, and more likely to travel before the rush-hour. This may be due to the greater flexibility in their work organization. The same applies to participants with higher incomes, who were significantly less likely to use public transport. Apparently, the higher VOT that is usually associated with a higher income, does not cause these participants to be less sensitive to the reward. Note also that whereas in the Yeti variant, high income travelers are less likely to travel by public transport, the effect is the reverse in the monetary scheme. It is not readily evident how this differences comes about.

With respect to personal characteristics, participants aged between 36 and 50 were more likely to work from home. Men were more likely than women to avoid the peak.

Finally, it appeared that when the reward of a Yeti was no longer relevant, the

participants were less likely to travel after the rush-hour or to work from home. When no reward was offered, the number of participants avoiding traffic decreased significantly.

6. CONCLUSIONS

This paper described the first outcomes of an experiment in which regular car travelers were stimulated to change their behavior by offering them positive monetary incentives or credits to obtain a smartphone. During a ten-week test period, participants in the experiments were confronted with different variants of monetary incentives and credit to earn a smartphone. The results suggest that all types of incentives resulted in a considerable reduction of peak car trips of participants. The initial percentage of about 45-50% could be reduced to about 20% of peak car travelers. The primary response to incentives is to retime the car commute to the periods before and after the morning peak. Mode switches only accounted for a relatively small share of the reduction in peak car traffic.

In case of monetary incentives, the lowest incentive (3€) accounted for the largest part of the reduction, while raising the reward to 7€ resulted in only an extra 7% reduction. In case of the Yeti smartphone incentive, a noteworthy finding is that without an incentive, but having access to traffic information, the share of in-peak car travelers decreases. This most likely signals that participants made arrangements to adjust their peak trips for the full duration of the trial.

In both the monetary and the Yeti variant, it is found that when the incentive ends, travelers return in majority to their common behavior, and frequently travel in the morning peak again. This suggests that the behavior displayed during the experiment is not sustained in the absence of continued incentives.

Finally, it is found that participants are more likely to adjust their behavior when they have flexible work hours, have public transport alternatives and regularly use traffic information. In addition, males, highly educated and high-income participants are more likely to avoid the peak in response to incentives.

Thus, the use of incentives can substantially reduce peak hour traffic, although the reduction is not sustained when the incentive ends. Although this finding points at some potential for the use of incentives, various issues remain to be answered. First, the results presented in this paper are based on a limited experiment. The question therefore is what effects can be expected if an incentive measure is applied on a larger scale. An important issue is to what extent the response to rewards by participants differs from the potential response of non-participants. To answer this question, a survey was carried out as part of the Spitsmijden project to compare the characteristics of participants and non-participants and to investigate why car drivers decide to participate (Ben-Elia and Ettema, 2009; Spitsmijden, 2007). The survey suggests that having flexibility in terms of work hours and absence of household obligations were important factors for choosing to participate in Spitsmijden, and participants and non-participants differed primarily with respect to these aspects. This suggests that the reduction of peak traffic found for the sample in this survey cannot be readily generalized to the total population, and that the question to what extent car drivers voluntarily participate in programs like Spitsmijden is crucial.

Second, the current paper has regarded behavioral response solely as a function of the incentive. In reality, travelers will trade-off the benefit of a shorter travel time and an incentive (e.g. in case of travelling before the peak) against the disutility of diverting from the preferred time. Consequently, the difference between travel times in and outside the peak will affect the decision. This implies that future analyses should also take travel time differences into account as a factor in the decision process. This is especially important since a large-scale application of incentives will affect the distribution of traffic across the morning peak, and thus the travel times at different periods. The use of predictive models that take into account incentive measures would require a valid representation of how travelers trade off travel time gains against the incentive.

Finally, it is noted that incentives, even when of the same size, can be offered in different formats. Instead of offering the amount as an incentive each time the desired behavior is displayed, an alternative option would be to give participants a lump sum from which an amount is subtracted each time one travels in the peak period. Although both approaches are formally equivalent, they use a different reference point and may therefore lead to different outcomes. This principle is called framing by Kahnemann and Tversky. Given the different formats which especially financial incentives can be formulated, it would be worthwhile to study such effects in more detail.

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