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Using economic incentives to influence drivers' route choices for safety enhancement: a cost-benefit analysis and the results from an empirical study

Jing Bie, corresponding author

Centre for Transport Studies
Faculty of Engineering Technology
University of Twente
P.O. Box 217
7500 AE Enschede
The Netherlands
Phone: +31-53-489 2543
Fax: +31-53-489 4040
E-mail: j.bie@utwente.nl

Bart van Arem

Department of Transport and Planning
Faculty of Civil Engineering and Geosciences
Delft University of Technology
The Netherlands

Muzaffar Igamberdiev

Centre for Transport Studies
Faculty of Engineering Technology
University of Twente
The Netherlands

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1 ABSTRACT

2 A route-based incentive program is introduced where drivers get rewarded for taking the safest
3 routes. The program is operated with an incentive structure by the logistic company and a
4 variable insurance premium scheme by the insurance company. The logistic company offers
5 incentives to its drivers for them to follow the safest routes, and by doing so expects to pay lower
6 insurance premiums for its vehicles. The insurance company charges a discounted premium for
7 vehicles which follow the safest routes, while expects to pay less for potential accident claims.
8 The theoretical framework, including the set up of the incentive structure and the variable
9 premium scheme, is presented in this paper. The cost benefit analysis is formulated for the
10 drivers, the logistic company and the insurance company. Drivers experience no loss from the
11 program; the existence of a win-win situation for the two companies is then examined.
12 Optimization of the incentive program is also formulated, which is a bi-level programming
13 problem. An online before-and-after survey is conducted to assess drivers' response to the
14 incentives. In total 45 Dutch professional drivers participated in the survey. The results show that
15 drivers tend to ignore safety-related information in making their route choices; however, the
16 incentives have some significant effects on these choices. The incentives therefore present an
17 efficient way of influencing drivers' route choices.

1. INTRODUCTION

Traffic safety depends on three major factors: the road infrastructure, the quality and safety level of vehicles, and the conduct of drivers (1,2,3). Many projects and programs have been initiated by both government and industry to improve traffic safety (4,5,6,7). An efficient way (in terms of the cost involved and the time scale) for traffic safety enhancement is to promote safe driving behavior. Many studies have explored the potential factors that may influence driver behavior and contribute to traffic safety improvement (3,8,9). The methods used for safety enhancement can be grouped into the following two categories: (a) the microscopic approach (10,11,12) looks at individual drivers and vehicles. It may assist the driver in the maneuver of the vehicle, such as speed maintenance, lane keeping and steering control. It can also help avoid collisions between vehicles and between vehicle and road-side objects or pedestrians, by enabling communication and better cooperation between the vehicles (V2V) and/or between the vehicle and the infrastructure (V2I); (b) the macroscopic approach looks at the network level of traffic flows. By controlling the distribution of traffic flow among the network, high safety may be achieved.

The macroscopic approach can be further divided into the following categories, based on how network flow control is carried out: (a) demand management, (b) temporal distribution management, and (c) spatial distribution management. Road pricing, although aimed to mitigate congestion, reduces travel demand and as a result may also improve traffic safety (13,14).

Temporal management involves the dispersion of traffic demand over time, such as peak hour restriction strategies. A Dutch practical test on rewarding drivers for peak hour avoidance shows that positive incentives are able to reduce the amount of peak traffic by 60-65% (15,16). Spatial management deals with the dispersion of the traffic demand over the road network (i.e. traffic assignment). In this study we are especially interested in the effect of drivers' route choice on traffic safety, since different routes have different safety levels (17). In particular, we will investigate the effect of using economic incentives to influence drivers' route choices.

Interventions in drivers' decision making process are realized by either enforcement or (positive) incentives. Enforcement normally involves legislation, such as speed limit and the prohibited use of hand-held mobile phones while driving. Drivers are punished (by warning, fine, or imprisonment) if they fail to comply with the prescribed rules. On the other hand, incentives, known as "soft measures," provide an extrinsic motivation for drivers to follow these rules, as doing so would bring them certain rewards. Research on using incentives to promote safe driving includes studies on safety belt use in the United States (18,19) as well as in the Netherlands (20,21). Incentive campaigns were shown to substantially stimulate safety belt use, with a short-term increase of 12 percentage points in average. Safety belt use dropped after withdrawal of the incentive campaigns but was generally still higher than initial baselines. A Dutch practical test on rewarding drivers for speed and headway keeping (22) and a Dutch pilot program on rewarding drivers for peak avoidance (15,16) showed similar results, observing considerable behavioral adaptation during the test but little remnant effects after the test. Another area of research focuses on using incentives to influence the decision to drive: the Pay-As-You-Drive (PAYD) insurance policy (23,24). In PAYD, the insurance premium is not fixed but based directly on the actual distance driven. Drivers then have an incentive to reduce vehicle use; as a result the number of traffic accidents can be reduced by up to 5.7% (25).

An important factor for accident exposure, besides vehicle maneuver and the driven distance, is the selection of routes between origins and destinations. Different routes have different characteristics in terms of road types, speed, congestion level and so on, all contributing to the safety level of the trip (17,26). According to statistics in the Netherlands (27), freeways are

1 the safest type of roads (on average 0.06~0.08 accidents per million vehicle kilometers),
2 compared to interurban roads (0.22~0.43) and urban roads (0.57~1.10). If incentives are
3 provided for drivers to follow “safe routes,” we could expect a decrease in traffic accident. To
4 study the potential benefit of such an incentive program, three interrelated subjects need to be
5 addressed: (a) architecture of the incentive program, i.e. selection of the “reward routes” and
6 design of the incentive structure (types and values of reward) (28); (b) drivers’ behavioral
7 adaptation in terms of route choice, in response to the incentive program; (c) traffic impact as a
8 direct result of drivers’ adapted behavior, such as effects on traffic accident occurrence (rates and
9 severity).

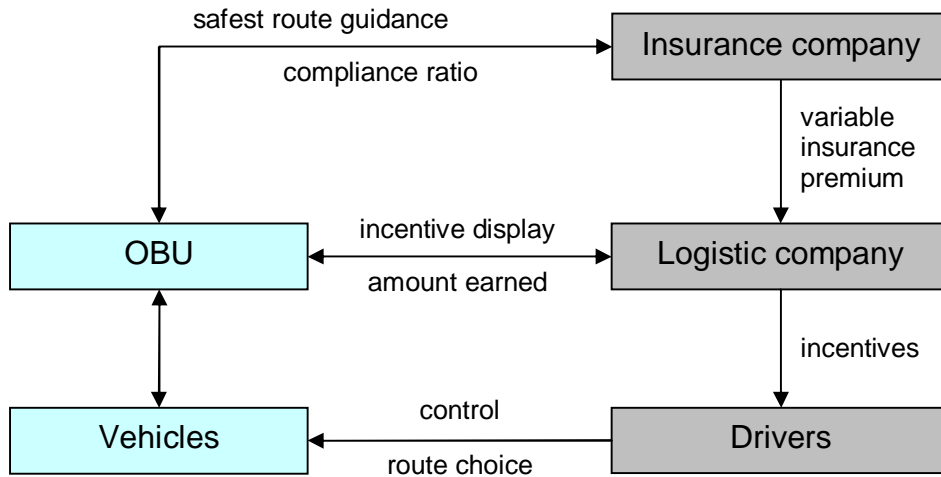
10 In this paper we focus on drivers’ reaction to the incentive program and the resulting
11 impact on the program operators, i.e. the subjects (b) and (c). We consider the operation of the
12 incentive program to be lead by a logistic company, who pays for insurance of its fleet and
13 employs professional drivers to drive the vehicles. The insurance company offers a variable
14 premium scheme, where discounts are made according to the compliance ratio with the safe
15 routes. The logistic company then decides the amount of incentives to be paid to drivers who
16 have followed the safe routes. The paper is organized as follows: Section 2 introduces the
17 theoretical framework of the incentive program. The variable insurance premium scheme and the
18 incentive structure are formulated, as well as drivers’ route choice behavior. In Section 3 cost-
19 benefit analyses are conducted for the individual drivers and for the two operating companies.
20 This is followed by the optimization problem of the incentive program. Section 4 includes the
21 description and data analysis of an online survey, which was designed to investigate driver
22 response to the incentive program. Finally Section 5 concludes the paper with some discussions
23 on future research topics.
24

25 **2. THEORETICAL FRAMEWORK OF THE INCENTIVE PROGRAM**

26 We consider the incentive program to be operated with an incentive structure and a variable
27 premium scheme. Three players are involved here: an insurance company, a logistic company,
28 and the professional drivers. The insurance company offers a variable insurance premium to the
29 vehicles owned by the logistic company. Different to traditional insurance packages of fixed
30 premium, the premium here varies according to the safety performance of the drivers. To make
31 this operational, the insurance company provides certain safety instructions and the premium is
32 dependent on how the instructions are followed. In our case, these safety instructions are realized
33 by presenting to the drivers the safest route for their trip and the insurance premium is discounted
34 if drivers comply with these instructions. The insurance company can decide on how these safest
35 routes are determined. An example is to follow the SWOV method (17, 26), where nine criteria
36 are used to assess the safety level of a route (these nine criteria encompass the composition of
37 road categories along the route, distance, travel time, number of left turns, and number of
38 intersections).

39 The logistic company employs professional drivers to drive the vehicles. In order to
40 encourage the drivers to follow the safest route guidance, the logistic company offers an
41 incentive structure which rewards the drivers if they follow the guidance. The drivers then decide
42 whether they will follow the route as they normally do, or switch to the safest route for which
43 they would receive a reward (i.e. the incentive). Figure 1 provides a general overview of the
44 operational scheme of the incentive program. An on-board unit (OBU) is equipped on the vehicle
45 with an embedded navigation system. It displays the safest route and the amount of route
46 incentives to the drivers; on the other hand, it records drivers’ actual route choice and then

1 calculate whether the driver followed the safest route or not and the amount of incentives the
 2 driver is eligible for.
 3



4
 5 **FIGURE 1 Operational framework of the incentive program.**
 6

7 **2.1. The Variable Insurance Premium Scheme**

8 Consider the N vehicles owned by the logistic company. It is assumed that each vehicle is only
 9 driven by a designated driver. The vehicles, as well as the drivers, can then be numerated as
 10 $1, 2, \dots, N$. For each vehicle, the annual insurance premium for a vehicle is dependent on its
 11 annual mileage and the percentage of the safest route being followed. This can be expressed as

12
$$v_i = f(M_i, g_i), \tag{1}$$

13 where v_i is the premium to be paid for vehicle i , M_i is the expected annual mileage for the
 14 vehicle, and g_i is the percentage at which the safest route is followed. The more frequently the
 15 safest route is followed, the lower the premium is. If a linear discount rate is applied, (1) is
 16 transformed to

17
$$v_i = v_{Mi} - r_i g_i. \tag{2}$$

18 Here r_i ($0 < r_i < v_{Mi}$) represents the reduced amount in insurance premium for the case of
 19 $g_i = 1$. That is, if the safest route is followed all the time, then the insurance to be paid is
 20 $v_{Mi} - r_i$. If the safest route is followed less frequently, the insurance to be paid will be some
 21 amount between $v_{Mi} - r_i$ and v_{Mi} .

22 The total amount of premiums that the insurance company will receive from the logistic
 23 company is then given as

24
$$V = \sum_{i=1}^N v_i = \sum_{i=1}^N (v_{Mi} - r_i g_i). \tag{3}$$

25 If the premiums are fixed rather than variable, v_{Mi} is the amount to be paid for vehicle i . The
 26 total amount is then

27
$$V_0 = \sum_{i=1}^N v_{Mi}. \tag{4}$$

1 The difference between (3) and (4), i.e. $V_0 - V$, is the reduced amount of insurance premiums
 2 paid by the logistic company to the insurance company. This difference is caused by the variable
 3 premium scheme. In terms of cost-benefit analysis, this amount accounts as a loss to the
 4 insurance company but a gain for the logistic company.

6 2.2. The Incentive Structure

7 The logistic company pays incentives to its drivers in order to encourage them to take up the
 8 safest routes when making their trips. For each trip, the safest route is determined by the
 9 insurance company and made known to drivers for each OD trip. This safest route might be
 10 different from the route that the driver would normally take when making the trip. The incentive
 11 then works as a stimulus for the drivers to switch to the safest route.

12 For an OD trip j made by driver i , denote b_{ij} as the amount of incentive awarded to the
 13 driver if they follow the safest route. If the probability that the driver will indeed follow this
 14 route is given by p_{ij} , then the expected amount of eventual incentive payout for this trip is $p_{ij}b_{ij}$.
 15 Denote J_i as the total number of trip per year for vehicle i . The compliance ratio g_i can be
 16 estimated by

$$17 \quad g_i = \frac{\sum_{j=1}^{J_i} p_{ij}}{J_i}. \quad (5)$$

18 The expected total amount of incentives paid out by the logistic company to the drivers is then
 19 given as

$$20 \quad B = \sum_{i=1}^N \sum_{j=1}^{J_i} p_{ij} b_{ij}. \quad (6)$$

22 2.3. Drivers' Route Choice Behavior

23 Random utility theory is applied to model drivers' route choice behavior. The logit model is
 24 adopted: when making OD trip j , the probability for an individual driver i to choose route r
 25 out of the available route set $\mathbf{R}_j = \{1, 2, \dots, m_j\}$ is given by

$$26 \quad p_{ijr} = \frac{e^{qu_r}}{\sum_{s=1}^{m_j} e^{qu_s}}. \quad (7)$$

27 Here u_r represents the utility of route r when making the OD trip j , and q is a dispersion
 28 parameter related to the driver's perception precision of the utilities on different routes.

29 Utility describes how desirable a route is and is formulated as a linear-in-form function of
 30 the route attributes:

$$31 \quad u_r = b_1 t_r + b_2 c_r + b_3 k_r + b_4 b_r, \quad (8)$$

32 where t_r is the travel time on route r , c_r is the fuel cost (and also any payable toll charge) along
 33 route r , k_r is a safety measure of route r , and b_r as introduced in §2.2 is the amount of
 34 incentive applicable to route r .

35 It can be argued that fuel cost does not concern the driver because in most of the cases the
 36 logistic company will cover such cost. However, we keep fuel cost as a component of the utility

1 function for consistency with other studies. When drivers do not pay the fuel cost themselves, we
2 can expect the value of b_2 in (8) to approach 0.

3 The safety component in (8) is included to see whether drivers take safety into account
4 even without incentives. It is also interesting to check whether the incentive structure will have
5 some “training” effect on the drivers’ route choice behavior, i.e. whether the incentive structure
6 will raise drivers’ awareness on route safety. This can be verified via an ABA sequential study
7 where A represents the case where no incentive structure is implemented and B presents the case
8 where the incentive structure is implemented. By observing drivers’ behavior through the
9 different phases we may identify different behavioral patterns in the two A phases; this
10 difference can be attributed to the temporary implementation of the incentive structure.

11 12 **3. EVALUATION AND OPTIMIZATION OF THE INCENTIVE PROGRAM**

13 The impact of the incentive structure and the variable premium scheme is analyzed here. For the
14 incentive program to be acceptable, it has to bring benefit to all players in the game. Cost benefit
15 analysis is made for the three players: the drivers, the logistic company, and the insurance
16 company. Furthermore, optimization of the program in order to minimize/maximize cost/benefit
17 is also discussed.

18 19 **3.1. Cost-Benefit Analysis for the Drivers**

20 We assume that the drivers/vehicles participating in this incentive scheme only contribute to a
21 very small amount of the total traffic flow in the network. And the incentive scheme changes
22 only these drivers’ behavior but not other drivers’ behavior. It is then reasonable to assert that the
23 changes of traffic conditions in the network with and without the incentive structure are
24 negligible. The attributes of the routes remains the same after the implementation of the
25 incentive structure, except that the safest routes have now an added utility of the incentive.

26 The effect of the incentive structure on the cost-benefit of the drivers is analyzed below
27 for all possible cases.

28 (i) If the incentive is rewarded to the route that the driver normally chooses, then, after
29 the implementation of the incentive structure, the drivers enjoys a gain equivalent to the amount
30 of the incentive paid.

31 (ii) If the incentive is rewarded to a route that the driver does not normally choose, then:
32 (a) if the new utility on the guided route, inclusive of the incentive, is higher than that of the
33 normal route, the driver switches to the guided route and gains the difference of the utilities of
34 the two routes; or (b) if the new utility on the guided route, inclusive of the incentive, is still
35 lower than the utility of the normal route, then the driver stays on the normal route. This way the
36 driver has no gain, neither any loss.

37 Drivers are then never at a loss because of the incentive structure. Therefore the
38 implementation of the incentive structure is always beneficial to the drivers and they will
39 welcome such a program.

40 41 **3.2. Cost-Benefit Analysis for the Logistic Company**

42 The logistic company plays the middle role in the game. It has interactions with both the
43 insurance company and the drivers it employed. The logistic company pays the insurance
44 premiums to the insurance company and it also offers the incentives for the drivers to follow the
45 safety instructions. Compared to the traditional case of fixed premium, the logistic company pays
46 less to insurance company but it also has to pay the additional cost of the incentives.

The logistic company's net benefit from the incentive program can be expressed as

$$Q_{LC} = V_0 - V - B. \tag{9}$$

If this amount is positive then the logistic company is at gain and benefits from the implementation of the incentive program. Further expanding the equation we have

$$Q_{LC} = \sum_{i=1}^N v_{Mi} - \sum_{i=1}^N (v_{Mi} - r_i g_i) - \sum_{i=1}^N \sum_{j=1}^{J_i} p_{ij} b_{ij} = \sum_{i=1}^N r_i g_i - \sum_{i=1}^N \sum_{j=1}^{J_i} p_{ij} b_{ij} \tag{10}$$

$$= \sum_{i=1}^N r_i \frac{\sum_{j=1}^{J_i} p_{ij}}{J_i} - \sum_{i=1}^N \sum_{j=1}^{J_i} p_{ij} b_{ij} = \sum_{i=1}^N \sum_{j=1}^{J_i} (\frac{r_i}{J_i} - b_{ij}) p_{ij}.$$

In (10), r_i is determined by the insurance company; the logistic company decides on b_{ij} which subsequently affect p_{ij} and g_i . We can see that as long as $b_{ij} < \frac{r_i}{J_i}$ is assured for all i, j then $Q_{LC} > 0$. This means that the amount of the incentives should not be too much; otherwise the logistic company would suffer a financial loss.

3.3. Cost-Benefit Analysis for the Insurance Company

The insurance company's profit is determined by revenue minus cost. Revenue comes from the collected premiums and cost goes for the accident claims which the insurance company has to pay out. The company gains if the decrease in claim pay-outs is bigger than the reduction of collected premiums. The company loses if the claim pay-outs does not decrease or decreases less than the reduced premiums.

The reduction in collected premiums is given by

$$\Delta V = V_0 - V = \sum_{i=1}^N r_i g_i. \tag{11}$$

The reduction in claim pay-out has to be estimated based on the different route safety levels. The expected accident cost for travelling along a route can be said to be directly related to the safety measure of the route. Here, by using accident cost instead of accident number, we have taken into account both accident occurrence and accident severity. If a linear relationship is assumed, then for vehicle i to make OD trip j along route r , the expected accident cost can be said to be $I(k - k_r)$; here $k - k_r$ gives a measure on route "unsafety" and I is the linear coefficient. The total expect accident cost, which will be recovered by insurance pay-out, is then sum as

$$K = \sum_{i=1}^N \sum_{j=1}^{J_i} \sum_{r=1}^{m_j} I(k - k_r) p_{ijr}. \tag{12}$$

Compare with the before period where no incentive structure was implemented, the same formula can be applied to estimate the total accident cost. The only difference lies in the different route choice probabilities. Taking $b_r = 0$ into (8) and then into (7) and then into (12) we have

$$u_r^{(0)} = b_1 t_r + b_2 c_r + b_3 k_r, \tag{13}$$

$$p_{ijr}^{(0)} = \frac{e^{q u_r^{(0)}}}{\sum_{s=1}^{m_j} e^{q u_s^{(0)}}}, \tag{14}$$

$$K_0 = \sum_{i=1}^N \sum_{j=1}^{J_i} \sum_{r=1}^{m_j} I(k - k_r) p_{ijr}^{(0)}. \quad (15)$$

The reduction in accident pay-out is then given by

$$\Delta K = K_0 - K. \quad (16)$$

The insurance company's net benefit from the incentive program is given as

$$Q_{IC} = \Delta K - \Delta V = K_0 - \sum_{i=1}^N \sum_{j=1}^{J_i} \sum_{r=1}^{m_j} I(k - k_r) (p_{ijr}^{(0)} - p_{ijr}) - \sum_{i=1}^N r_i g_i. \quad (17)$$

3.4. Optimization of the Incentive Program

Optimization of the incentive program can be formulated as a bi-level problem. Both the insurance company and the logistic company try to maximize their benefit, the former by means of settings in the variable premium scheme and the latter by means of settings in the incentive structure. The bi-level programming problem can be expressed as

$$\text{upper level: } \max_{r_i} Q_{IC}; \quad (18)$$

$$\text{lower level: } \max_{b_{ij}} Q_{LC}. \quad (19)$$

On both levels we see a trade-off between two cancelling measures. For the logistic company, if the incentives are high in value then drivers' compliance level will expectedly be high and as a result the premium rates will be lowered substantially. This way the logistic company pays more to the drivers and less to the insurance company. If incentives are lowered, the logistic company pays less to the drivers but more to the insurance company.

For the insurance company, if very competitive premium rates are offered for high compliance vehicles (i.e. with high r_i), then we expect the incentives, the compliance ratio, and subsequently the safety to be high. This means that the accident pay-out will be low. This way the insurance company receives less revenue while paying out less accident costs. If the rates are not so competitive (i.e. with low r_i), revenue will be higher but so is the expected accident pay-out due to low compliance of safety instructions.

The same trade-off also applies to the individual drivers. If they do not comply with the safety instructions they will not receive any bonus but may well save travel time or fuel cost. Even though the drivers have no direct control of the variable premium scheme or the incentive structure, they indirectly influence them through their route choice behavior.

A win-win situation is said to exist when

$$Q_{LC} \geq 0, Q_{IC} \geq 0. \quad (20)$$

Equivalently, this means

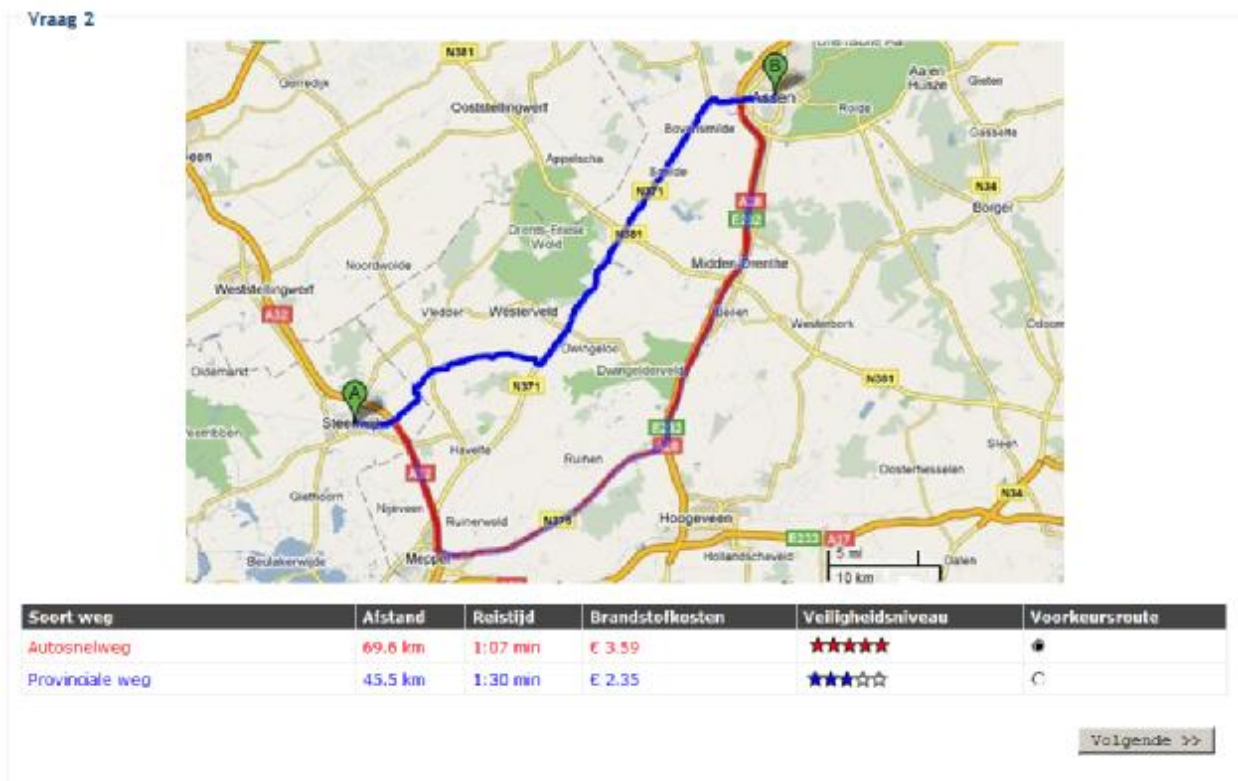
$$K_0 - K \geq V_0 - V \geq B. \quad (21)$$

The inequalities in (21) are actually the necessary and sufficient conditions for a win-win situation. Based on the bi-level formulation in (18) and (19), we expect that the optimization of the incentive program will reduce the logistic company's benefit to its minimum (maybe even to zero, depending on the parameterization). This is because the insurance company, being at the upper level of the optimization, will choose the premium discount rate r_i in such a way that the difference between $K_0 - K$ and $V_0 - V$ (i.e. its own benefit) is maximized. By doing so, the difference between $V_0 - V$ and B (i.e. the logistic company's benefit) is minimized. In practice,

1 we expect the insurance company to choose r_i so that a reasonable benefit is also assured for the
 2 logistic company, in order to persuade the latter to participate in the incentive program.

3
 4 **4. THE RESULTS AND IMPLICATIONS FROM AN ONLINE SURVEY**

5 We developed an online Route Choice Survey (RCS) to study drivers' response to the incentive
 6 structure. The survey was located on a web-server (available at <http://www.routekeuze.eu>). The
 7 target group was Dutch professional drivers and for this reason the interface was prepared in the
 8 Dutch language. In the beginning of the survey some background information is given to the
 9 respondent, explaining the incentive structure and describing the choice situation. In the main
 10 part of the survey, 20 choice questions are presented to the respondent. These include 10
 11 "before" questions (i.e. without the incentives; Figure 2), followed by 10 "after" questions (i.e.
 12 with the incentives; Figure 3).
 13



14
 15 **FIGURE 2 Screenshot of a before question (without the incentives).**
 16

17 Each choice question consists of a question map and an answer module. The question
 18 map displays the route choice situation. Origin and destination are presented by A and B,
 19 respectively. Two options are highlighted on the map: the safest route (red color) and the
 20 alternative route (blue color). The answer module presents the properties of two options,
 21 including road type, route distance, travel time, fuel cost and safety scores (represented by 1~5
 22 filled stars). For the after questions the module further includes a column of the amount of
 23 incentives (*beloning*). Respondents make their route choices by clicking on the radio buttons
 24 right next to the options in the answer module. After a selection is made the 'Next' (*Volgende*)
 25 button will be activated and the respondent may proceed to the next question.

1 In total, 20 choice situations (i.e. with 20 different maps) are used. These include road
 2 networks from the Netherlands (NL), from Europe but outside the Netherlands (EU) and from
 3 the United States (US). For each respondent, a random sample of 10 choice situations are
 4 presented as before questions (i.e. without the incentives displayed; see Figure 2) and the rest 10
 5 choice situations are presented as after questions (Figure 3). In this way each respondent will
 6 face 20 different choice maps while the same choice map has an equal opportunity to be
 7 presented as a before question or as an after question. When a large number of respondents have
 8 participated in the survey, a choice map will expectedly have equal numbers of before answers
 9 and after answers.

10



11
 12 **FIGURE 3 Screenshot of an after question (with the incentives).**

13

14 **4.1. The Preliminary Results**

15 The online survey was conducted between June 4 and June 24, 2009. Respondents were attracted
 16 by contacting logistic and service companies; the web link of the survey was then distributed via
 17 their internal email systems. In the end, a total of 45 professional drivers answered the survey.
 18 Not every one of them completed the 20 questions in whole, resulting in 438 answers for before
 19 questions and 356 answers for after questions. Of the 794 answers in total, 283 were made on NL
 20 maps, 355 on EU maps, and 156 on US maps.

21 Table 1 shows the distribution of the choice answers. A clear difference is observed in the
 22 probability of the safest route being chosen against its alternative without or with the incentive
 23 structure: an average of 50% for the before questions, compared to 58% for the after questions. A
 24 t-test on the 20 pairs of percentages reveals that the after percentages are significantly greater
 25 than the before percentages (at significance level $\alpha = 0.05$; t value = 2.31, critical t value =
 26 1.73). Despite the significant difference, we notice nonetheless that 5 out of the 20 choice maps

1 observed a decrease rather than increase in the percentage of choosing the safest route. This
 2 observation is beyond our explanation. However, we note that these 5 cases happened only to
 3 European road networks (the two non-Dutch ones being in Italy and Switzerland, respectively),
 4 which the respondents are more familiar with than American road networks.

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6
7

TABLE 1 Route Choice Survey: Choice Counts Before and After

Map	Location	Before questions			After questions			Change in % choosing safest route
		# choosing safest route	# choosing alternative route	% choosing safest route	# choosing safest route	# choosing alternative route	% choosing safest route	
1	EU	21	2	91.3	15	0	100.0	8.7
2	EU	21	5	80.8	14	1	93.3	12.6
3	EU	6	10	37.5	14	12	53.8	16.3
4	EU	18	6	75.0	9	9	50.0	-25.0
5	EU	15	9	62.5	9	8	52.9	-9.6
6	US	3	18	14.3	7	13	35.0	20.7
7	US	14	9	60.9	11	7	61.1	0.2
8	US	3	19	13.6	9	5	64.3	50.6
9	US	18	7	72.0	11	2	84.6	12.6
10	US	7	14	33.3	6	9	40.0	6.7
11	NL	7	15	31.8	5	13	27.8	-4.0
12	NL	6	13	31.6	19	1	95.0	63.4
13	NL	12	12	50.0	9	7	56.3	6.3
14	NL	18	7	72.0	11	7	61.1	-10.9
15	NL	7	14	33.3	11	9	55.0	21.7
16	NL	9	12	42.9	5	12	29.4	-13.4
17	NL	13	9	59.1	12	8	60.0	0.9
18	EU	7	11	38.9	13	6	68.4	29.5
19	EU	6	16	27.3	7	11	38.9	11.6
20	EU	8	11	42.1	11	8	57.9	15.8
Total		219	219	50.0	208	148	58.4	8.4

8
9

4.2. Estimation of the Route Choice Model

10 Although the results in Table 1 give some indication on drivers' behavior shift, they do not take
 11 into account the differences between the individual choice situations. The gap between the two
 12 options in terms of travel time, fuel cost, and the amount of the incentive, will certainly affect
 13 drivers' preference towards/against the safest route. Therefore the survey data were also used to
 14 estimate the logit choice model.

15 Table 2 shows the regression results of the logit route choice model (8). Note here the
 16 units of the attributes used in the sample data: t_r (minute), c_r (euro), k_r (safety star, 1~5), b_r
 17 (euro). The dispersion parameter q is fixed at 1. Insignificant parameters are marked with an
 18 asterisk. Overall the results for different sample groups are consistent with each other, taking into
 19 account the following facts: (a) the dispersion parameter is fixed at 1 for all groups; (b) travel
 20 time and fuel cost are correlated in the choice questions; (c) safety levels and the incentives are
 21 correlated in the choice questions.

22 The regression results are also consistent with the assumptions that travel time and fuel
 23 cost contribute negatively to the route utilities, while safety and reward contribute positively.

24 These lead to negative b_1 's and b_2 's, and positive b_3 's and b_4 's in the regression results. The

only exceptions are: b_3 for before only and after only, b_2 and b_3 for US. In all four cases the parameter is insignificant, indicating that the sign of the parameter is less important because of its proximity to zero. Besides, the correlations discussed above may account for these irregularities.

The results show that drivers do take the reward into account, to an extent that reward is more important than fuel cost (compare the magnitude of b_2 and b_4). In contrast, drivers consider to a much lesser degree the safety level of a route (insignificant b_3). This implies that reward can be an effective way to encourage drivers to take the safest routes.

TABLE 2 Utility Parameters of Logit Route Choice Model: Regression Results

	All	Before only	After only	NL	EU	US
Sample size	794	438	356	283	355	156
β_1	-0.0425	-0.0556	-0.0446	-0.00540*	-0.160	-0.129
β_2	-0.279	-0.0988*	-0.881	-0.987	-0.310	0.143*
β_3	0.0427*	-0.180*	-0.0556*	0.598	0.171*	-0.434*
β_4	0.434	0	1.24	0.683	0.402	0.460

*: insignificant.

4.3. Cost-Benefit Analysis for the Logistic Company and the Insurance Company

The cost-benefit balances for the logistic company and the insurance company apparently depend on the road network and the types of trips made. As an indicative numerical test, we consider the trip situation illustrated in Figure 2 and apply the route choice model with the parameters as the regression results for all samples in Table 2. Before the incentive program is implemented, choice probabilities for the safest route and the alternative route are 0.672 and 0.328, respectively. The expected safety level as expressed in 1~5 stars is then $5 \cdot 0.672 + 3 \cdot 0.328 = 4.34$.

With the incentive program where €1 is awarded for following the safest route, the choice probabilities become 0.760 and 0.240. And the expected safety level is now $5 \cdot 0.760 + 3 \cdot 0.240 = 4.52$. So by expectedly paying $B = 0.760 \cdot €1 = €0.76$, the logistic company raises the safety level by 0.18 star. If the resulting reduction in expected accident cost is greater than €0.76, say $\Delta K = €1$, then the variable insurance premium can offer a discount of $\Delta V = €0.80$. By doing so the insurance company has a net benefit of €0.20 for this trip, while the logistic company receives a benefit of €0.04. A win-win situation is then established.

5. CONCLUSIONS AND DISCUSSIONS

This paper introduced an innovative approach for traffic safety enhancement, namely a route-based incentive program operated by a logistic company together with an insurance company. A win-win situation for the two companies was demonstrated to exist dependent on driver behavior, the road network, as well as the settings in the incentive program. The next step of our research is to further develop the theoretical framework and to conduct a more comprehensive cost benefit analysis for the stakeholders.

The online survey used in this study is a stated preference technique to investigate driver behavior in future situations. In order to draw solid conclusions we intend to attract more respondents than the current amount of 45. On the other hand, when the incentive program is put into practice, the actual driver behavior (i.e. revealed preference) may differ. One of our ongoing studies is a pilot program where professional drivers from an energy service company take parts

1 and their vehicles are equipped with the OBU's. The results from this practical test will verify
2 any discrepancy between the stated and revealed behavior patterns.

3 The impact of several assumptions in this paper needs to be addressed in follow up
4 studies. In particular, the benefit of the logistic company depends on not only the safety aspects
5 but also other factors such as cost and operation efficiency. If drivers take longer route because
6 of the incentive program, higher fuel cost is expected which is in the end carried by the logistic
7 company. Due to longer travel time per journey, the number of deliveries that a vehicle can do
8 per day might also be reduced. A more comprehensive cost benefit analysis is therefore
9 necessary from the logistic company's point of view.

10 Adopting the incentive program on a societal level is also a point of interest for future
11 studies. Similar (but contrary) to road pricing, drivers pay for the marginal cost they incur on
12 society and get rewarded for the marginal benefit they bring to society (by taking safer routes).
13 For this implementation social acceptance and financial viability must be assessed beforehand.

14 It is also important to realize the complexity of the traffic system; many settings may be
15 "tuned" in an effort to optimize the incentive program. The two most essential factors would be
16 location (e.g. highway, or around city centre) and timing (e.g. dynamic, peak hour only). If
17 training effects on the drivers are expected, the incentive program can be planned to be
18 temporary, while achieving a long term effect nevertheless. Another issue is the "shockwave" in
19 network flow right after the program is implemented (29). This can be modeled as a dynamical
20 system problem.

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