

Context-dependent influence of road attributes and pricing policies on route choice behavior of truck drivers: results of a conjoint choice experiment

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Abstract In this paper, we report the results of a stated choice experiment, which was conducted to examine truck drivers' route choice behavior. Of particular interest are the questions (i) what is the relative importance of road accessibility considerations via-a-vis traditional factors influencing route choice behavior, (ii) what are the influences of particular personal and situational variables on the evaluation of route attributes, (iii) how sensitive are truck drivers for possible pricing policies, and (iv) is there a difference in impact if environmental concerns are framed as a bonus or as a pricing instrument. The main findings indicate that road accessibility characteristics have a substantial impact on route preferences which is of the same order of magnitude as variation in travel times. This suggests that provision of adequate travel information in itself can be an effective instrument to prevent negative externalities of good transport associated with shortest routes. Furthermore, the results indicate that truck drivers/route planners when choosing a route are relatively sensitive to road pricing schemes and rather insensitive to environmental bonuses.

Keywords Freight transport · Route choice · Price policies · Stated choice experiment

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Introduction

Navigation systems have gained rapidly in popularity. Many cars are now routinely equipped with such systems; if not, a large percentage of car owners have bought auxiliary equipment. In addition to personal travel, navigation systems, integrated with tracking systems, seem to have become the norm in freight transport as well. The broad acceptance and rapid diffusion of navigation systems have stimulated many potentially relevant ideas for the next generation of navigation systems. Examples include the use of real time (e.g. a traffic jam) as opposed to static, average traffic information, the coupling with location-based services and even the use of navigation systems for inducing travellers to use specific routes and avoid others.

For goods transport, however, current navigation systems do not fully take into account the special requirements trucks impose on routes. On the one hand, these requirements have to do with physical or legal constraints that block access of certain roads for trucks, such as environmental zoning regulations, headroom, maximum axle weight and the like. Provided that data are available about such constraints, it is straightforward to avoid such roads in route recommendations. In addition, however, they relate to preferences that need to be traded-off against each other. Generally, truck drivers wish to avoid obstacles such as sharp curves, strong crosswinds (occurring at crossovers), road intersections, residential area, etc. The fewer such obstacles a road has the more convenient using the road for a truck driver will be. In the following we will use the term road accessibility to refer to this performance aspect of a road. Little is known in a quantitative sense how truck drivers trade-off road accessibility characteristics against travel time and travel costs factors. Only few behavioural studies on route choice decision-making of truck drivers can be found in the existing literature. Empirical studies by Kawamura (2002), Knorrning et al. (2005) and Vadali et al. (2009) consider the trade-off behaviour of truck drivers among distances, times and/or toll costs when faced with multiple routes. Road accessibility factors have not received much attention in quantitative research to date.

Furthermore, there are environmental concerns related to drivers' choice of route either or not guided by a navigation system. Although these concerns hold for passenger and freight transport in general, they are particularly pronounced for the latter segment given the heavier vehicles involved. Road pricing is a well-known instrument to reduce traffic congestion. In the area of passenger transport there is a large body of empirical literature on the influence of road/congestion pricing on travel behaviour choice. Holguín-Veras et al. (2006) is one of the few studies examining this for freight transport. They found that carriers were sensitive to pricing strategy corresponding to off-hour delivery. Adelakun and Cherry (2009) found also that truck drivers are willing to pay to avoid congestion. Other recent studies provide further empirical support for this (Vadali et al. 2009; Zhou and Baker 2009). The form of financial incentives has received some attention. An environmental bonus has been suggested as a potentially relevant, new transport management instrument, considering an objective to induce drivers of trucks and vans to choose routes that, from an environmental perspective, are friendlier. For example, a bonus or incentive such as tax deduction is thought to be effective in moving freight delivery traffic to off-hours (Holguín-Veras 2008). Greenberg (2009) recently discussed the design problem of regulatory incentives by converting fixed insurance costs to per-mile charges where people pay as they drive and save as they don't. The impact of this new instrument is difficult to judge. In passenger transport, effectiveness of a bonus system to invoke drivers to avoid peak hours in their commute trips has recently been investigated in a large scale field experiment in the Netherlands (Ben Elia and Ettema 2009).

The purpose of the present study is to gain more insight in route preferences of truck drivers and planners, with the aim (1) to define characteristics of truck-friendly routes and (2) to assess likely effects of possible price policies. A conjoint experiment is an efficient method of collecting data for discrete choice analysis as an alternative to a field experiment. The experiment that we conduct focuses on short-distance freight transport by companies that operate on a local level; it is that segment of freight transport that, particularly, is involved in possible use of local roads where environmental burden is an issue. To evaluate effectiveness of possible pricing policies, we designed the experiment in such a way that the influence of the sign of the incentive (price or a bonus) can be estimated independently of the influence of its (absolute) level. This allows us to evaluate relative effectiveness of a bonus system compared to a road-pricing system. Company planners often play a dominant role in route planning and, hence, route choices also depend on their preferences. Both parties were therefore asked to participate in the experiment. We use the mixed logit model to analyse a central tendency as well as heterogeneity in choice preferences of truck drivers/planners. Furthermore, we test the extent to which preferences are dependent on contextual and person characteristics. This paper reports the main findings of this study. It is organized as follows. First, we will describe the sample. This is followed by a description of the design of the conjoint choice experiment and a discussion of the results. We conclude the paper with a summary of major conclusions and a discussion of problems remaining for future research.

Sample

The present study is part of a project commissioned by authorities of the extended Eindhoven region, the Netherlands, and the Dutch Ministry of Transportation. The project is concerned with the introduction of tailored navigation systems for trucks and aims to assess user preferences regarding these systems and likely impacts on aggregate traffic flows when these new systems are introduced on a large scale. Logistics is an important sector of economy in this region. The region has a highly developed high-tech industry sector and is located in the corridor from Rotterdam main harbor to Germany. In a general call published in local media, freight transport companies that are active in the Eindhoven region and operate locally (i.e. carry out local deliveries within the region) were invited to participate in the project. In total, 15 companies were selected in such a way that own carriers and transport companies were both represented in reasonable proportions and the sample represents existing diversity also in terms of nature of freight and size of vehicles. As intended, the companies vary in nature and are representative of the spectrum of businesses with local transport in this economic region. Apart from that intention, the selection was random. The route choice experiment was part of the larger project. A contact person at each company was asked to invite route planners (if any) and truck drivers within the company to fill out the questionnaire that included the experiment. In total, 100 drivers and a maximum of one planner per company constituted the sample frame for the present experiment.

Conjoint choice experiment

Eliciting attributes

An examination of the relevant literature suggests that, apart from costs, several attributes may be important in influencing route choice behavior of company planners and drivers of

trucks and vans. Lin (2001) found that the freight routing problem of time-definite common carriers is one of finding the routes that minimize the sum of handling and transportation costs, while meeting service commitments and operational restrictions. Because handling charges are fixed in the short run, this suggests that transportation costs, which are a function of travel distance and travel time, are an influential variable. Cullinane and Toy (2000) also identified influential attributes in freight route and mode choice decisions. Based on seventy-five articles relevant to the subject of freight route choice decisions, they concluded that costs, speed, transit time reliability and characteristics of the goods and service are of the highest importance. Zhang et al. (2009) conducted a questionnaire survey among private-owner truck drivers and assumed that delivery costs and network performance/traffic congestion are the most important factors for selecting a route. Previous (conjoint analysis) studies on passenger route choice analysis can also contribute, albeit partly, to selecting influential factors for freight route choice (e.g. Caussade et al. 2005; Hensher and Greene 2003). Factors such as travel time, congestion and distance, which are essential for passenger route choice, are potentially of the same importance to the freight transport sector, and were therefore included in the experiment.

In addition to a literature survey, qualitative in-depth interviews with experts were held to identify relevant attributes and context variables. The final list of attributes and context variables included and the levels varied in the experiment are shown in Table 1. Consistently, choice sets presented to respondents include two route alternatives. The distance to destination was varied as a context variable. Given our specific interest in local freight transport, we focused on relatively short-distance trips. We used two levels for distance in the short-distance domain, namely 10 and 30 km. These distance levels are merely defining an order of magnitude of the length of the trip; the exact distance may depend on the route. In the remaining of this section, we will explain the variables describing the route alternatives and context variables in more detail.

Pricing scenarios

As explained in the introduction, one aim of our study is to measure responsiveness of truck drivers (and planners) to financial incentives of different forms. Given this aim, a road bonus and a road price were included as attribute variables of route alternatives in the experiment. Road pricing did not require much introduction as drivers generally are aware of the fact that at the time of the experiment this policy is proposed to be implemented in the near future in the Netherlands. On the other hand, road bonus was introduced to respondents as a policy instrument that our national government might consider in the future to stimulate drivers to choose routes that are preferable considering environmental impacts and traffic safety. To avoid confusion and reduce task complexity, respondents were asked either to respond to a road-bonus or a road-pricing scenario and they were randomly assigned to one of these scenarios. In absolute terms, the same price levels were used in the bonus and price scenario, so that in effect only the label (it is an environment bonus vs. it is a congestion charge) differed between the scenarios. Three levels were assumed: no price/bonus, a low tariff and a high tariff. The low tariff was set to 11 Euro cent/km and the high tariff to 22 Euro cent/km. The choice of these levels was based, on the one hand, on current estimates of values-of-time for freight transport and, on the other, on price levels policy makers in the Netherlands are currently considering for implementing a road-pricing system. In presenting choice alternatives the levels were specified as a total amount depending on the actual length of the trip. In case of both scenarios, it was explained to respondents that they should assume that not the driver/planner personally but the company is charged/benefits.

Table 1 Influential attributes and levels used in the conjoint choice experiment

Variables	No.	Levels and their coding		Values		
		Levels	Coding	Short distance	Long distance	Unit
Attribute variables						
Congestion	1	No congestion	(1, 0)	0	0	min
	2	Medium delay	(-1, -1)	+5	+15	min
	3	Long delay	(0, 1)	+10	+30	min
Road category	1	Highway	(1, 0)			
	2	Main road	(-1, -1)			
	3	Local road	(0, 1)			
Bonus/Pricing	1	None	(1, 0)	0	0	€
	2	Medium level	(-1, -1)	1.10	3.30	€
	3	High level	(0, 1)	2.20	6.60	€
Passing through urban area	1	No	(1, 0)			
	2	Yes, and without school	(-1, -1)			
	3	Yes, and with school	(0, 1)			
Having restaurant facility	1	No	(1)			
	2	Yes	(-1)			
Context variables						
Normal travel time	1	Shortest and longer route +10%		10 and 11	30 and 33	min
	2	Shortest and longer route +25%		10 and 13	30 and 37	min
	3	Shortest and longer route +50%		10 and 15	30 and 45	min
Time of day	1	Morning	(1, 0)			
	2	Lunch time	(-1, -1)			
	3	End of day	(0, 1)			
Size of truck	1	<3.5 ton	(1, 0)			
	2	3.5 – <30 ton	(-1, -1)			
	3	>30 ton	(0, 1)			
Distance to destination	1	Short: 15 km	(1)			
	2	Long: 30 km	(-1)			
Time since rest	1	Short	(1)			
	2	Long	(-1)			
Time window	1	Narrow	(1)			
	2	Wide	(-1)			
Person variables						
Age	1	Younger than 40 years	(1)			
	2	Older than 40 years	(-1)			
Job	1	Driver	(1)			
	2	Planner	(-1)			

Other attributes and context variables

Whereas distance to destination is specified as a context variable for the trip, travel time is defined as an attribute of a route alternative. Assuming that arbitrarily one of the two routes has the shortest travel time, only the travel time of the other route was varied. Technically, this means that travel time is a context variable, as it is defined on the level of a choice set. The shortest travel time was set to 10 and 30 min for the short (10 km) and long distance trips (30 km), respectively. For the longer route, three levels are assumed, namely an increase of 10, 25 and 50% relative to the shortest travel time. The actual travel times were presented in absolute terms (i.e. in minutes). They were presented as expected travel times when no congestion occurs. Congestion is included as an additional attribute and is specified as a longer travel time. Three levels are distinguished: no congestion, somewhat longer travel time (a delay of 5 and 15 min for a 10 and 30 km trip, respectively) and a much longer travel time (a delay of 10 and 30 min for 10 and 30 km trip). It was explained to respondents that when a longer travel time is specified they should assume that it is very likely that the delay will actually occur. We chose this way of presenting the information to simulate a likely future where navigation systems are able to predict actual delays fairly reliably based on actual traffic information.

Apart from travel times and costs (price or bonus), several other attributes were included that relate to special concerns in freight transport which emerged from the interviews. First, road category is an important indicator of accessibility of the road, as it correlates in ways well-known by drivers with presence of (soft) obstacles such as horizontal curves, vertical curves (slopes) and intersections (and traffic signals). A three-way classification generally defines the road categories important to drivers and was used in the experiment: highway (national roads), main way (provincial roads) and local road. In this classification, highways and main ways are both accessible to fast, motorized vehicles only. The main differences are that highways in contrast to main ways have multiple lanes for each traffic direction (to facilitate overtaking), have no equal level intersections and conform to higher design standards so that they allow higher travel speeds. With regard to obstacles, drivers generally prefer highways over main ways and main ways over local roads. Second, the interviews indicated that truck drivers wish to avoid routes that pass through residential area and school zones, because of obstacles, such as narrow cross sections, and unsafe traffic conditions such areas may bring along. To accommodate these concerns, three levels were distinguished for an urban area attribute: no urban area, urban area but not residential area and residential area including schools. Third, availability of restaurant and rest facilities along the route was included as a two-level variable in the experiment.

In addition to attributes of route alternatives, also several context variables were varied in the experiment. These include distance to destination, size of the truck, time of day, time since rest and width of the available time window. As above mentioned, distance to destination defines an order of magnitude for the trip length distinguishing the levels 10 and 30 km. Truck size is potentially a significant contextual factor, as drivers of large trucks may find low-category roads (with accompanying obstacles such as curves, slopes and intersections) and passing through residential area, particularly, objectionable. Type of vehicle was not varied: in all size cases a straight truck was assumed. For time of day and time since rest, no strong effects were anticipated. A reason for including them in the experiment was that they may increase a sense of reality and, thus, help respondents to make a vivid imagination of a presented choice situation. Time of day is detailed as: in the morning, during lunch time and at the end of the day. Time since rest was presented in qualitative terms as long and short. It was explained that long should be taken to mean that it is about

time for a break. Finally, the time window relates to the time schedule of goods delivery. The levels of this variable were defined qualitatively as ‘there is ample time’ and ‘time is tight’, the latter meaning that the time window would not allow a delay during the trip.

Experimental design

On the level of attributes, the experiment involves a $3^4 \times 2^1$ full factorial design of route alternatives. Since not all possible multi-way interactions are relevant, a more efficient design is feasible. An orthogonal fractional design including 27 profiles was selected. This design allows the estimation of main effects of the attribute variables and of three two-way interactions between attributes. It should be noted that, even though the design is orthogonal, the two levels of the restaurant-facility attribute are not completely balanced. This means that main effects of attributes cannot be estimated independently of possible interactions with this two-level attribute. However, because we do not expect significant interactions regarding this attribute, we preferred this design over an alternative where the 2-level attribute is balanced, but which would require more profiles (trials). We expect that two-way interactions are particularly relevant for the road category variable. This variable may interact with the urban-area variable, in the sense that for a highway the influence of urban area (three levels) is likely negligible. Also other attributes such as facilities to rest, congestion and others may be evaluated differently depending on road category. The three two-way interactions that the experimental design allowed estimating were therefore used to capture interactions with the road category variable. Since the (route) choice alternatives are unlabeled, choice sets per respondent were composed by each time drawing randomly without replacement two profiles from this design (see below). The use of random generation of choice sets is well-established in applications of stated choice experiments (Louviere 1998).

Context variables may influence the subjective evaluation of the attributes and therefore the design of the experiment should also allow the estimation of possible context effects. Context effects can be measured in conjoint choice experiments by using design strategies that allow one to vary the contextual variables independently from the attribute profiles (Oppewal and Timmermans 1991). Therefore, we used a separate design to vary the context variables across choice sets. As can be read from Table 1, the context variables included imply a $3^3 \times 2^3$ full factorial design of contexts. Again, since not all possible multi-way interactions are relevant, a more efficient orthogonal design consisting of a fraction of 27 profiles could be defined. This design allows us to estimate main effects as well as three two-way interaction effects. Again, the design does not display attribute level balance for the two-level attributes involved with as a consequence that not all main effects of attributes are independent of interactions with the two-level attributes. However, the design matches are primary purpose to investigate whether interactions exist between these context variables, on the one hand, and route attributes, on the other, and is more compact than an alternative design that does display such balance. For each choice set, the context was determined by randomly drawing a profile from this design. Again, this was done without replacement for choice sets generated for a same respondent (see below). In this way, context and attribute profiles varied independently of each other.

Representation of choice alternatives

Most conjoint choice studies use verbal representations of attribute levels. This means of representation impose an extra burden, as respondents need to construct mental representations based on textual descriptions (Arentze et al. 2003). To aid respondents in

constructing mental representations, several route choice studies have used graphs or images to represent levels of attributes (e.g. Bogers et al. 2006; Chorus and Timmermans 2009; Levinson and Tilahun 2008). However, the kinds of representation used in these studies are still highly abstract. Given the fact that our experiment includes a relatively large number of attribute variables, an effective visualization of the attributes is considered especially important here. Therefore, in the present study, we used an iconic representation that should allow respondents to quickly capture the context variables and attribute levels describing choice alternatives. The icons used are consistent with conventions of map representations drivers are generally familiar with and, at the same time, avoids too detailed visualizations (e.g. photographs) that may distract the respondent from the choice task or evoke irrelevant associations (Timmermans and Hato 2009). An example is shown in Fig. 1a which includes information of levels of restaurant and parking, size of truck, school zones, urban area and road category. A legend explaining the mapping of icons to variable levels was provided to the respondents and is shown in Fig. 1b.

Evidently, given the large number of profiles, it would be very time-consuming to prepare these iconic representations manually. Therefore, a special computer program was written that generated these visualizations given the definition of the attribute profiles underlying a choice set.

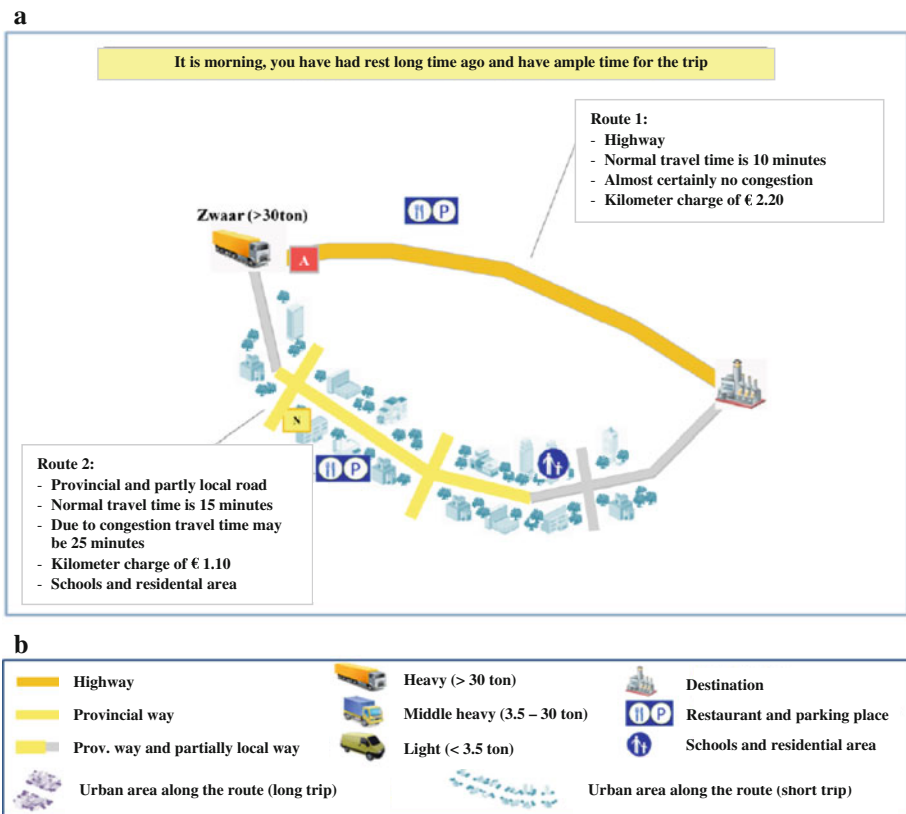


Fig. 1 a Sample profiles for short trip. b Legend for icon information

Administration

Apart from the experiment, the questionnaire included questions intended to obtain some background information of the respondent with respect to socio-demographics (e.g. age), the company where he/she works and the job he/she has in the company. The questionnaire was implemented as a web application put on line in a 2 week time period in July 2009. A link to the website was sent to each company with a request to distribute it to all truck drivers and (route) planners within the company. Each respondent received 10 choice sets, where each choice set has two alternatives. Respondents were asked to indicate “which route they prefer” for each choice set.

Random generation of choice sets was implemented as follows. All possible choice-sets were precompiled as unique combinations of two profiles from the attribute design. Each respondent is randomly assigned to either the road-bonus or road-pricing scheme. The 10 choice-sets a respondent receives are randomly drawn from the compiled set. Each time, the chosen choice sets are labeled and a next respondent gets the choice sets from the rest. When all choice sets have been chosen once, labels are removed and the process is repeated. The context profiles that are presented with choice sets are selected from the context design in the same way. In sum, this procedure ensures that (1) each respondent gets unique choice sets without duplications, (2) the selection of choice sets and contexts is random and (3) across respondents the choice-sets and contexts are balanced.

Analysis and results

Sample characteristics

In total, 81 respondents completed the part of the questionnaire about person characteristics and a total of 78 respondents completed the full set of 10 choice tasks; thus, three respondents quitted the questionnaire during the survey process. Table 2 shows descriptive statistics on some of the key variables related to person characteristics. Size of the truck and average distance referred to the vehicles and trips the person usually deals with (either as a planner or a driver). A substantial proportion of trips relates to the short-distance category as a result of our sampling frame. Regarding the job, the questionnaire provided three options, i.e. driver, planner and other, where multiple choices are possible. As we anticipated, some of the respondents are both driver and planner. It appears that 90.1% of respondents are drivers, 4.9% are planners and only 3.7% combine both functions in their job. Most respondents are between 40 and 50 years of age. Furthermore, most of them deal (as a driver or planner) with a middle size truck and only very few people with vans, i.e. vehicles that have a smaller weight than 3.5 ton.

Model estimation

The choice data were analyzed using a mixed logit model. All attribute variables were effect-coded using the middle (or the last) category as the reference category. This means that each attribute variable is represented by $n - 1$ indicator variables (where n is the number of levels). For a variable with three levels, for example, these indicator variables are coded as follows. The first level is coded as $[1, 0]$, the second level as $[-1, -1]$ and the third level as $[0, 1]$. Coded in this way the effects of the three levels are represented as $[\beta_1, \beta_2, \beta_3]$ where β_1 and β_3 are estimated values and β_2 can be calculated as

Table 2 Results of descriptive statistics

Factors		Frequency	Percent
Age	<30 years	14	17.3
	30–40 years	19	23.5
	40–50 years	34	42.0
	≥50 years	13	16.0
Missing		1	1.2
Total		81	100.0
Job	Driver	73	90.1
	Planner	4	4.9
	Both driver and planner	3	3.7
Missing		1	1.2
Total		81	100.0
Size of truck	Heavy (>30 ton)	30	37.0
	Middle (3.5–30 ton)	42	51.9
	Light (<3.5 ton)	4	4.9
	Light and Middle	2	2.5
	Middle and Heavy	3	3.7
Total		81	100.0
Average distance	<10 km	3	3.7
	10–20 km	7	11.1
	20–49 km	1	7.4
	50+ km	61	75.3
Missing		2	2.5
Total		81	100.0

$\beta_2 = -\beta_1 - \beta_3$. Thus, the parameters show effects of each level of the base variable relative to an average (utility) value. Context variables were also effect coded using the same system. Parameters were estimated for each interaction between context and attribute indicator variable. Each estimated parameter, thus, shows the increase or decrease of the effect of the concerned attribute level caused by the concerned level of the context variable. In the following, we will use the term contrast parameters to indicate these interactions. Background variables of the respondent were also considered as possibly relevant context variables. Although ratio and interval measurement scales allow the estimation of a single parameter, we used effect coding also for these variables to allow for possible non-linear or, more in general, discontinuous effects. Travel time is the only exception. The effect of travel time appeared to have approximately a logarithmic form. Therefore, we estimated a single parameter assuming this form to obtain a more efficient and equally fitting model. Existence of random taste variation was tested for each main effect variable after controlling for context effects. A lognormal distribution was assumed for these coefficients and 10,000 Halton draws implemented for a Monte Carlo Likelihood estimation. Those that appeared to be not significant were included as fixed coefficients in a final specification of the model.

Results of parameter estimation, shown in Table 3, include both main effects of attributes and interaction effects with context variables. Figure 2 shows the main effects graphically. In terms of person variables, we investigated interactions with age, job, truck size and distance variables. Potentially, there are many interaction effects; only those interaction effects that

Table 3 Model estimation results

Group	Variable	Estimate		<i>t</i> value	<i>P</i> value
Attribute	Time (log)	-4.579	**	-4.904	0.000
	<i>Congestion (1)</i>	1.512	**	4.524	0.000
	Congestion (3)	-0.989	**	-4.596	0.000
	Road category (1)	1.132	**	4.594	0.000
	Road category (3)	-0.799	**	-4.188	0.000
	<i>Road pricing (1)</i>	1.036	**	3.132	0.002
	Road pricing (3)	-1.053	**	-3.665	0.000
	Bonus (1)	-0.269		-1.615	0.106
	Bonus (3)	0.047		0.265	0.791
	Urban area (1)	0.450	**	2.832	0.005
	Urban area (3)	-0.669	**	-3.964	0.000
	Restaurant	-0.127		-1.403	0.161
Congestion	Congestion (1) × time since rest	0.418	**	2.477	0.132
	Congestion (3) × time since rest	-0.071		-0.533	0.594
Road	Road category (1) × truck (1)	0.035		0.202	0.840
	Road category (3) × truck (1)	0.323	*	1.873	0.061
	Road category (1) × truck (3)	-0.055		-0.314	0.753
	Road category (3) × truck (3)	-0.229		-1.363	0.173
	Road category (1) × age	0.392	**	2.665	0.008
	Road category (3) × age	-0.249	*	-1.912	0.056
	Road category (1) × time window	-0.269	*	-1.862	0.063
Road category (3) × time window	0.071		0.533	0.594	
Road pricing	Road pricing (1) × truck (1)	0.519		1.423	0.155
	Road pricing (3) × truck (1)	-0.526	*	-1.802	0.072
	Road pricing (1) × truck (3)	-0.256		-0.758	0.448
	Road pricing (3) × truck (3)	0.365		1.360	0.174
	Road pricing (1) × distance	-0.512	*	-1.868	0.062
	Road pricing (3) × distance	0.433	*	1.855	0.064
Urban area	Urban area (1) × time since rest	0.288	**	2.051	0.040
	Urban area (3) × time since rest	-0.269	*	-1.823	0.068
	Urban area (1) × time of day (1)	0.026		0.147	0.883
	Urban area (3) × time of day (1)	0.146		0.824	0.410
	Urban area (1) × time of day (3)	0.402	**	2.351	0.019
	Urban area (3) × time of day (3)	-0.227		-1.232	0.218

Standard deviation of random parameters

Road pricing (1)	1.566	**	2.284	0.022
Congestion (1)	1.120	**	2.114	0.035
Sample size				780
LL(0)				-540.65
LL(β)				-384.55
ρ^2				0.289
ρ^2 adjusted				0.254

Italics label random parameters

** and * 5 and 10% significant, respectively

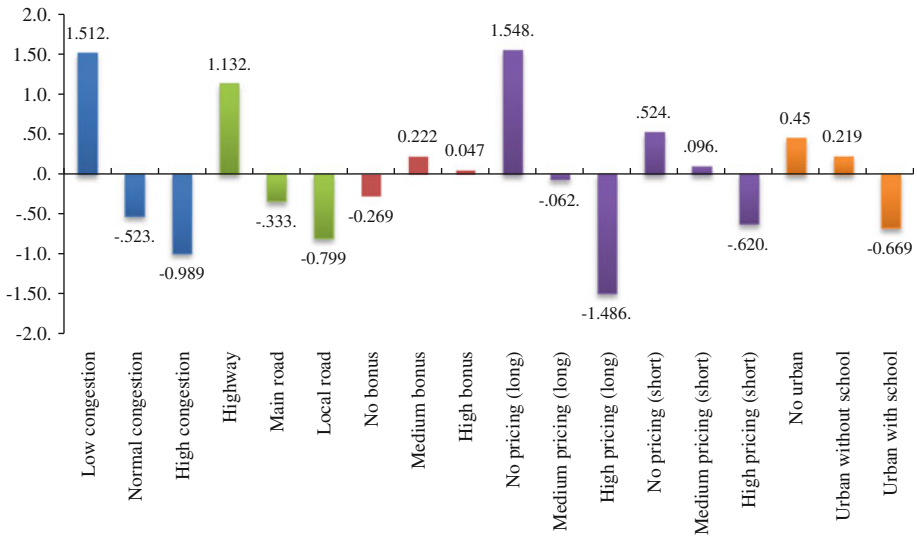


Fig. 2 Utilities of main effect variables

appeared to be significant were included in the final specification of the model of which the estimation results are shown in Table 3. A person or context variable is considered significant for an attribute if at least one of the contrast parameters for the attribute variable is statistically significant at the 5% alpha level. The total fit of the model is acceptable (McFadden's rho square is 0.289, adjusted rho square is 0.254), most of the parameters, at least for the main effects, are significant at 5% and all parameters that are significant have signs as expected. The estimates reveal the following main and interaction effects.

Travel time appears to be the most significant attribute among all variables. In line with findings from other route-choice studies, the congestion variable also has a strongly significant impact on route choice. Drivers (and planners) avoid congestion even when it involves only a moderate delay. The variable interacts with time since rest. A short time since rest increases a preference for non-congested roads. Furthermore, significance of the estimated standard deviation indicates that random taste variation plays a role.

As expected, road category has a strong influence as well. Keeping everything else constant, drivers have a strong preference for highway as well as a strong dislike of local roads. At the same time, these preferences interact with several context variables. First, the size of the truck has an influence. As could be expected, the dislike of local roads is somewhat smaller when the truck is of the light category. In other words, drivers/planners avoid local roads particularly in case of a heavier truck. Furthermore, we see that the (base) preference for highway decreases when the time window is narrow. A likely explanation is that, in the eyes of the drivers, road category correlates with a probability of a delay, such that highway loses its attractiveness when time constraints do not allow any delay. Another possible explanation is that, because highways have limited access and do not offer a way out, a truck might become trapped when traffic comes to a halt (e.g. because of an incident) which has more severe consequences if the time window is narrow. Because a high probability of delay was controlled for, this represents an anticipation of positive but low probabilities of a delay. Interestingly, the preference for road category also appears to interact with a personal background variable. Younger drivers (i.e. younger than 40 years of age) display a stronger preference for highway compared to the older age category. The

explanation for this is not clear, but it may be due to the phenomenon that drivers of younger age, who have used navigation systems all of their life, have less knowledge of routes and prefer highways because these roads tend to be easier in terms of way-finding.

The urban-area variable has a significant effect on route choice as well. Drivers have a relatively strong preference for routes that do not pass through urbanized area and a strong dislike for routes that pass through residential areas and school zones in particular. Interaction effects on this level indicate that the preference for avoiding urban area is particularly strong at the end of the day. Probably, this indicates that drivers anticipate worsened traffic conditions at this later moment of the day. Interestingly, there is also an interaction effect based on time since rest. A short time since rest further increases a preference for avoiding residential area and school zones. A possible explanation is that under decreased temporal constraints, other than travel time factors (related to convenience) become more important.

Availability of a place to rest and/or eat (e.g. a restaurant) has no significant effect on route choice. This suggests that presence of such facilities along the route can be ignored in travel-information services for truck drivers; at least this information seems less useful.

Having considered physical attributes, we now turn to the pricing variables (road pricing and road bonus) that may become reality in the future for the truck drivers. As it turns out, road pricing has a much bigger effect on route choice than a (environmental) bonus. For road pricing, the deterring effect of a high tariff (22 cent/km) is of the same order of magnitude (-1.053) as that of a high delay due to congestion (-0.989). The interaction with trip distance reflects that in absolute terms the price increases with distance traveled so that the effect is larger for the longer distance trips compared to the short-distance trips. Furthermore, an interaction with truck size indicates that drivers/planners are considerably more sensitive to road price when the truck is of the light category. The standard deviation of the estimated distribution for zero congestion price is significant. On the other hand, a bonus appears to have no significant effect on route choice. Furthermore, we find no effects of context variables and no significant taste heterogeneity on this level.

Thus, our results indicate that road pricing has a significant effect. To get an indication of the size of the effect, we can relate it to the estimated coefficient for travel time or, more precisely, to the log of the travel time. Then we find for example that on average a road price of 0.11 Euro cent/km is equivalent to an extra 12.6 min travel time for a 30 km trip, whereas a road price of 0.22 Euro cent/km is equivalent to an extra 28.2 min travel time for a same trip. This illustrates the extent to which drivers, on average, are willing to accept longer routes for avoiding congestion price. Finally, it is worth noting that we did not find significant effects of role—driver or planner—on the evaluation of attributes. This may be due to a small sample size of planners, but nevertheless indicates that if differences exist they will not be big.

Conclusions and discussion

Operations in the good transport sector are much aided by navigation and route planning systems that are tailored to the specific needs and requirements of trucks and good delivery. At the same time, environmental concerns and the question to what extent route choice behavior can be influenced by price policies are becoming increasingly relevant. In this paper we presented the results of a conjoint choice experiment that was designed to measure quantitatively truck drivers' and route planners' preferences and their sensitivity to possible pricing policies. Relevant attribute and context variables were identified

through in-depth interviews among experts, and congestion price and environmental bonus were considered as possible pricing instruments. They were varied based on orthogonal fractions of factorial designs and carefully visualized to reduce task complexity and enhance realism. The experiment was implemented in a web application and administered on the internet. A representative sample of truck drivers and route planners in terms of diversity of types of transport in the Eindhoven region participated in the experiment.

The results indicate that truck drivers/planners have a relatively strong base preference for highways and wish to avoid local roads. The preference is particularly strong in case of heavy vehicles and is, roughly, of the same order of magnitude as a preference to avoid traffic congestion. As strong as a dislike for local roads is a preference to avoid routes that run through residential area and school zones. Local roads as well as residential area involve obstacles and drivers are willing to accept a longer travel time when needed to avoid them. Also, travel time delays due to congestion appear to be a major deterrent in route choice. In terms of possible pricing policy instruments, our results indicate that route choice in freight transport is much more sensitive to road-pricing than (environmental) road-bonus schemes. The results suggest that realistic road pricing schemes would be roughly as effective to evoke shifts in route choice as travel delays caused by congestion are. Price sensitivity is, however, dependent on the weight of the vehicle. Sensitivity is significantly less in case of heavy vehicles. The difference in sensitiveness between congestion price and road bonus suggests that price sensitivity is asymmetric.

These findings indicate that routes that truck drivers prefer—larger roads and avoiding residential area—coincide with routes that are beneficial from an environmental and traffic-safety perspective. This means that providing adequate (and up to date) travel information to drivers/planners can be an effective way in itself to reduce negative externalities of good-transport traffic. On the other hand, the study provides evidence that road pricing schemes can be an effective means to influence routes that trucks take, whereas much less effect can be expected from an environmental bonus instrument. This is consistent with a more general finding that human decision makers tend to be more strongly deterred from losses than attracted by gains of a same amount. In that sense, our results are consistent with prospect theory, which states that people are risk seekers in the domain of losses and risk avoiders in the domain of gains (Kahneman and Tversky 1979; Tversky and Kahneman 1981; Avineri and Prasker 2006).

This study has revealed the trade-offs truck drivers/planners make in route choice. The quantitative estimates can readily be used to fine-tune new navigation systems for truck drivers. Several problems are worth considering in future research. Although already a range of context variables were tested in this study, it is worthwhile to repeat the experiment for a larger sample that would allow detecting smaller effects on the level of context variables and person/company variables than we presently could identify. Furthermore, our analysis revealed taste variation for several attribute variables in our analysis that could not be explained by observed background variables. Identification of clusters in preference patterns among drivers is interesting and could be performed by estimating a latent class model on the data. Finally, our focus has been on freight transport on a local scale. Whether route preferences are the same for long distance transport is furthermore a relevant question that future research could address.

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