Investigating Drivers' Behaviour and Time Sacrifice under Social Routing Advices

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SHORT SUMMARY

Trip information and navigation systems are expected to become key components of future traffic management strategies, contributing to mitigate car usage externalities. In this study, we investigate social routing advices, which could be associated with nudges and delivered via a navigation app, aiming at promoting sustainable routing behaviour, where some drivers are asked to take longer routes and make travel time sacrifices (TTS) instead of minimizing personal travel time. To investigate the impacts of various types of information strategies and social goals on drivers' social routing behaviour, we present a stated choice experiment performed in two European cities, Amsterdam and Helsinki, and applied an ordered logit model. The results show that drivers are less inclined to make TTS for nudges related to liveability compared with other social goals. Regardless of the goal, almost 30% of drivers are willing to accept a social route that is 40% longer than the shortest route.

Keywords: Sustainable routing, Traffic management, Transport economics and policy.

1. INTRODUCTION

Route choice conventionally takes place under *user equilibrium* conditions, in which drivers are assumed to be rational and selfish, namely they aim at achieving the highest individual benefits. On the other hand, to prioritize the benefits for all users, a *system optimum* condition should be achieved (van Essen et al., 2016). This implies that some drivers may need to travel along longer routes, which causes travel time sacrifice (TTS) for the benefit of other drivers. In this paper, this behaviour is denoted as *social routing behaviour* and the alternative route is called *socially responsible route* (SRR).

Investigating the impacts of traveler information systems on the overall traffic pattern is not a new topic. In fact, in the 90s, several studies focused on route choice and dynamic traffic equilibrium under travel information (Ben-Akiva et al., 1991; Friesz et al., 1994; Hall, 1996; Bierlaire, 1996). When it comes to travel time sacrifices and taking a detour for the sake of all travellers in a network, not all drivers always behave socially. The share of drivers that comply with social routing advice is called *compliance rate*. A large body of literature exists on the compliance with trip information and social routing advices, as well as on factors affecting the compliance rate. Among consistent findings, TTS (Djavadian et al., 2014), the information strategy (Mariotte et al., 2021), the degree of trust in information (Zhong et al., 2012), and the goal of detour (van Essen et al., 2020) are decisive elements in the compliance rate with routing advice.

Despite the rich body of literature in the field of compliance, little attention is paid to the amount of TTS, mostly treated as an influential factor in compliance rate (Mariotte et al., 2021). Thus, a research question can be defined as "what levels of TTS are likely to be acceptable for various social goals?". Moreover, little is known about the impacts of different types of information strategies on TTS: this leads to another research question “how do different types of information strategies affect the level of TTS?”. Accordingly, the present study contributes to the existing literature by investigating the impacts of different information strategies on TTS and identifying drivers’ behaviours for different social goals. This aims at helping transportation planners to design and offer the most appropriate SRR in order to achieve the desired social goals.

To address the above questions, we present here a stated choice experiment conducted in two European cities, Amsterdam, the Netherlands, and Helsinki, Finland, to investigate different levels of TTS under various social goals and information strategies.

2. METHODOLOGY

Survey design

For this study, an online questionnaire was designed comprising three main parts. The first part collects background information, consisting of sociodemographic information, driving-related experience, typical travel patterns, and work/study status. In the second part, drivers’ attitudes towards the environment, sustainability, traffic jam, and the willingness to change driving patterns to support more sustainable traffic are surveyed. In the third part, 10 stated choices are defined in which respondents are presented a hypothetical commute trip toward the city center, where they have to choose between two different routes: a baseline (shortest) route that takes 20 minutes, and the SRR that has a longer travel time but contributes to one of predefined social goal.

To investigate the drivers’ inclination to TTS for various goals, three different goals are introduced to the participants that are among the most important challenges that cities encounter due to urbanization: *liveability* (e.g., by avoiding residential areas), *safety* (e.g., by avoiding school zones), and *emission reduction*. Also, three information strategies were developed and named after strategies in van Essen et al. (2020): nudge, social reinforcement, and incentive. Each strategy with a specific level of information aims at influencing personal route choice to improve network efficiency.

Statistical analysis of this data can provide us with many valuable conclusions regarding the impacts of the way the recommendation is intended on TTS, as well as people’s inclination towards various social goals in the different European cities.

Ordered logit model

Besides statistical analysis, employing discrete choice models can provide a better understanding of the factors affecting TTS. In this study, an ordered logit model (Greene and Hensher, 2010) is applied to the data obtained from the online questionnaire. Ordered logit models are used to estimate relationships between a dependent variable (e.g., level of TTS) and a set of independent variables (e.g., a given pair of information strategy and social goal) when the dependent variable is measured on an ordinal scale. In this model, the probability of observing outcome i is

$$P_i = \Pr(\kappa_{i-1} < U_i < \kappa_i) = \Pr(\kappa_{i-1} < \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_n x_{ni} + \varepsilon_i \le \kappa_i) \quad (1)$$

where U_i is the utility function of outcome i, β_n is a model coefficient, x_{ni} is an independent variable for outcome i, ε_i is the random error term, and κ_i is the i^{th} cut point (i=1, 2, …, K, where K is the number of possible outcomes). κ_0 and κ_K are taken as -∞ and +∞, respectively. Coefficients and cut points are estimated using a maximum likelihood method.

Participants

The online questionnaire was delivered to 90 participants in Amsterdam and Helsinki, who heard about the survey on social media/websites and registered based on a self-assessment of eligibility, from September to November 2021. In the end, 66 participants (44 from Helsinki and 22 from Amsterdam) completed the questionnaire. Table 1 summarizes the sociodemographic characteristics of the total sample, including respondents in Helsinki and Amsterdam. The sample shows an overrepresentation of male respondents (75%); all age classes are well represented, although the number of participants over 60 years old is relatively small.

Table 1: Sample sociodemographic characteristics

		Total (N=66) %	Helsinki (N=44) %	Amsterdam (N=22) %
Gender				
	Male	75	76	73
	Female	23	24	23
	Other	2	0	5
Age				
	18-29	16	14	18
	30-39	28	33	18
	40-49	31	29	36
	50-59	23	24	23
	≥ 60	2	0	5
Education				
	Highschool diploma	19	26	5
	Bachelor	39	33	50
	Master	36	33	41
	Other	6	7	5
Annual household income				
	<20K	2	2	0
	20K – 40K	9	10	9
	40K – 60K	16	21	5
	60K – 80K	19	19	18
	80K – 100K	14	17	9
	>100K	17	17	18
	Prefer not to answer	23	14	41
Household size				
	1	17	17	18
	2	44	40	50
	3	16	19	9
	≥ 4	23	24	23

Hypothetical scenarios

There are 10 hypothetical situations in which respondents have to choose among the following 4 different options: (1) I would never take a longer route to contribute to the social goal; I would take the SRR if travel time was up to (2) 2 min longer: 22 min; (3) 5 min longer: 25 min; or (4) 8 min longer: 28 min.

Figure 1 shows the information that appeared to the participants under the nudge strategy in the navigation app. Given the travel time of both routes, as well as negative aspects of the usual route and positive aspects of the SRR, respondents were asked to choose their TTS for achieving a more liveable city, a safer city, or a cleaner city (3 hypothetical scenarios).

Figure 1: Nudge strategy

In the social reinforcement strategy, in addition to the information in the nudge strategy, a driver receives information on the choices of other drivers, i.e., the percentage of drivers who have been asked to take the SRR and complied with our advice, as shown in Figure 2. In the survey, we assume three different levels of compliance to determine the effect of different levels of reinforcement on TTS for liveability (3 hypothetical scenarios): 50%, 70%, and 90%. Hereafter, this strategy is referred to as Reinforcement-xx, where xx shows the compliance rate of other drivers.

Figure 2: Reinforcement strategy

Incentive strategy advises drivers to take another route than their usual, and in return, they will receive a (monetary) reward. Thus, besides the information in the nudge strategy, a driver is informed about the monetary rewards (see Figure 3). We defined two forms of incentives for achieving a more liveable city (2 hypothetical scenarios): a gamification approach, where10 points equal to 2€ that can be used for activities in the city, and 1€ cash. The choices of SRR for safety and emission reduction were only considered under the 10-point incentive (2 hypothetical scenarios).

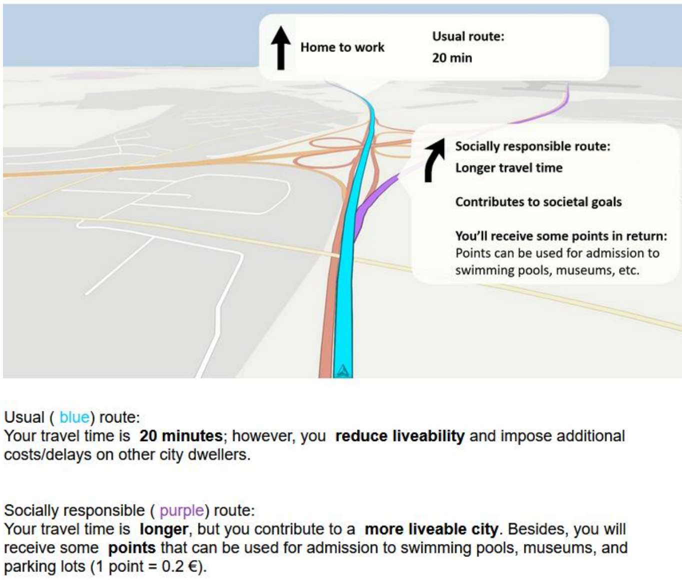

Figure 3: Incentive strategy

3. RESULTS AND DISCUSSION

Statistical analysis of travel time sacrifice

Under all 10 scenarios, more than 95% of the respondents claim to comply with the advice and take the SRR with different levels of TTS. This compliance rate is significantly higher than what was stated in previous studies (e.g., 57% in van Essen et al. (2021)) probably due to offering an up to 2-min longer route that is a quite intangible increase in travel time. Table 1 shows the share of drivers who sacrifice up to 2, 5, and 8 minutes in all 10 scenarios.

According to Table 1, for liveability, half of the respondents take the SRR with 10% longer travel time under the nudge strategy, while under 5 other strategies, the biggest shares of drivers are likely to take SRR with 25% longer travel time. This actively demonstrates that less TTS for liveability takes place under the nudge strategy compared with the other strategies, indicating that people care less about liveability than the other two social goals.

If drivers are informed that 90% of other drivers who received social routing advice for liveability follow it, the share of drivers willing to take longer routes increases. With a 90% of compliance rate, the percentage of drivers who take the 40% longer routes is 7% higher than the 50% compliance rate (15% vs 8%), meaning that, if drivers know that more drivers sacrifice, they are more willing to take longer routes and make bigger TTS.

Interestingly, the results indicate that monetary incentives kind of flatten the goals so that, regardless of the goal, drivers accept longer travel time compared with the nudge strategy. Almost half of the drivers take 25% longer SRR, and more than 30% take 40% longer SRR for all three social goals. The two types of incentives do not produce substantial differences. This implies that less amount of cash works as effectively as higher values of points in order to achieve liveability.

Table 1: Share of drivers (%) who sacrifice up to 2, 5, and 8 minutes

Social goal / TTS / Information strategy	Liveability			Safety			Emission reduction		
	Up to 2 min (10%)	Up to 5 min (25%)	Up to 8 min (40%)	Up to 2 min (10%)	Up to 5 min (25%)	Up to 8 min (40%)	Up to 2 min (10%)	Up to 5 min (25%)	Up to 8 min (40%)
Nudge	50	42	6	33	48	17	29	55	12
Reinforcement-50	36	53	8	-	-	-	-	-	-
Reinforcement-70	36	48	11	-	-	-	-	-	-
Reinforcement-90	30	50	15	-	-	-	-	-	-
Incentive (10 points)	20	48	30	17	48	33	15	50	33
Incentive (1€)	26	42	30	-	-	-	-	-	-

Figure 4 and Figure 5 present the share of respondents with different levels of TTS for different social goals under nudge and incentive strategies, in Helsinki and Amsterdam. Accordingly, in Amsterdam, everyone takes the socially responsible route. This may be caused by the insufficient number of participants in Amsterdam, and/or a more biased sample. Also, in Amsterdam, under the nudge strategy, participants make the biggest TTS for emission reduction (see Figure 4) where 18% and 50% of respondents state that they take 40% and 25% longer SRR, respectively; in Helsinki, participants make the biggest TTS for safety where 16% of respondents stated that they take 40% longer SRR. However, according to Figure 5, under the incentive strategy, it is the opposite: the biggest TTS is for emission reduction in Helsinki and safety in Amsterdam. This finding implies that the effects of information strategies on TTS vary geographically.

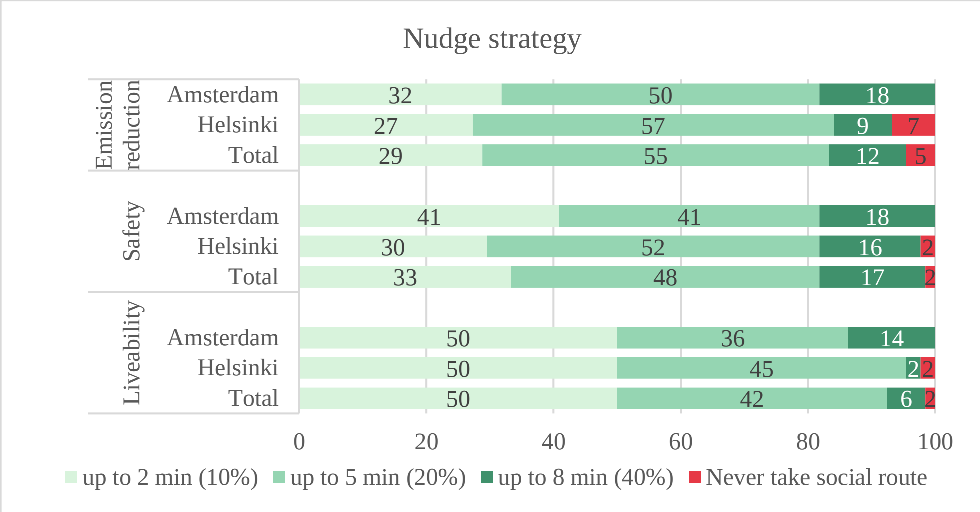

Figure 4: TTS for various social goals under the Nudge strategy in Helsinki and Amsterdam

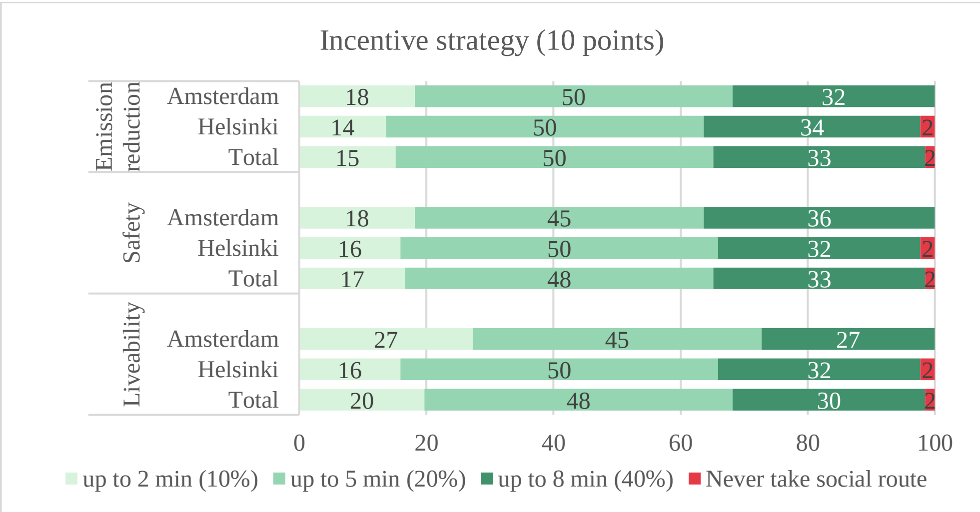

Figure 5: TTS for various social goals under the Incentive strategy in Helsinki and Amsterdam

Ordered logit model

Table 2 presents the estimation results of an ordered logit model based on 660 observations (66 respondents x 10 scenarios) using Stata. According to this table, TTS for liveability is significantly less than for emission reduction. This confirms the findings of the statistical analysis section. Furthermore, TTS for safety is not significantly different from emission reduction.

Regarding the way routing advice is intended, the performance of Reinforcement-50 and Reinforcement-70 are not significantly different from the nudge strategy. However, Reinforcement-90 and the incentive strategies positively influence TTS, meaning that under these information strategies, drivers make heavier TTS than with the nudge strategy. Still, the impact of the incentive strategy is stronger than Reinforcement-90 (1.14 vs. 0.48). As discussed earlier, no significant difference is observed between the two types of monetary incentives, demonstrating that 1€ cash is as strong as 10 points (=2 €).

Table 2: Ordered Logit model results

		Value	Std. errs.	t	P
Coefficients	Goals (Ref.: Emission reduction)				
	Liveability	-0.41	0.23	-1.77	0.08
	Safety	0.03	0.23	0.14	0.89
	Information strategies (Ref.: Nudge)				
	Reinforcement-50	0.21	0.29	0.70	0.48
	Reinforcement-70	0.20	0.30	0.68	0.50
	Reinforcement-90	0.48	0.30	1.63	0.10
	Incentive (10 points)	1.14	0.20	5.84	0.00
	Incentive (1€)	1.14	0.31	3.69	0.00
Cut points	cut1	-3.47	0.30	-11.55	0.00
	cut2	-0.53	0.19	-2.75	0.01
	cut3	1.80	0.21	8.73	0.00
Model specifications	χ^2	54.40 (Prob>χ^2=0.00)			
	Pseudo R^2	0.037			

4. CONCLUSIONS

The importance of using social routing advices to improve network efficiency was confirmed previously (van Essen et al., 2020; Djavadian et al., 2014; Kerkman et al., 2012), and the rate of complying with the social routing advice is widely studied. Instead of focusing on the compliance rate, this study addresses TTS that drivers are ready to make for various social goals under different information strategies. To this end, this study describes the results of a stated choice experiment conducted in Helsinki and Amsterdam and an ordered logit model applied to the data.

Several results emerge that provide provisional answers to the two research questions posed in Section 1.

(1) *What levels of TTS are likely to be acceptable for various social goals*?

Given the nudge strategy, participants are more willing to take longer routes for emission reduction compared with safety and liveability. Looking into each city, Helsinki participants are more likely to make a bigger TTS for safety than emission reduction: 16% and 9% stated that they take 40% longer SRR for safety and emission reduction, respectively. This suggests that the levels of TTS for each social goal may vary geographically. Under the incentive strategy, no significant difference is found between various social goals, except for liveability in Amsterdam which is less desired than other social goals.

(2) *How do different types of information strategies affect the level of TTS*?

For liveability, the nudge strategy is not statistically different from Reinforcement-50 and Reinforcement-70, however, compared with Reinforcement-90 and the incentive strategies, it makes the least motivation for TTS. For safety and emission reduction also the nudge strategy makes the least motivation for TTS compared with the incentive strategy. Interestingly, monetary incentives (in the form of cash and points) smooth the effects of social goals. They incentivize more than 30% of respondents to make 40% TTS, and more than 40% of respondents to make 25% TTS.

Overall, the results suggest that the level of TTS depends on the type of information strategy, social goal, and geographical area. If a higher level of TTS is needed to achieve a system optimum in a network, the road authority might consider implementing monetary incentives. Social reinforcement with 90% compliance is at the next level for liveability. Since reinforcement has not been investigated for safety and emission reduction, it is impossible to rank the information strategies for those goals.

The analysis in this paper could be extended in several directions. The impact of sociodemographic information, driving-related characteristics, travel patterns, and drivers' attitudes toward TTS also should be investigated. Moreover, determining the difference between revealed and stated choices would be of interest.

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