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Investigating the compliance of travelers with the recommendation of socially desirable alternatives

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SHORT SUMMARY

The development of Advanced Traveler Information Systems (ATIS) with en-route navigation systems has opened the door to new traffic regulation policies such as collective route guidance based on the minimization of total travel time. However, a critical element for their efficiency is the compliance of travelers with route recommendations. In this paper, we use a stated preference survey based on route choice situations from a real network to investigate traveler compliance for different levels of travel time sacrifice vs several social benefits. Two kinds of social benefits are considered: congestion alleviation and emission reduction. The data collected allows us to precisely quantify the travel time sacrifice that a given proportion of travelers would be ready to accept in order to take a different alternative that has a given level of social benefit. In line with the literature, our analysis confirms the decrease of compliance with the increase of sacrifice. Moreover, it suggests that the way the recommendation is intended could play a significant role in the level of compliance: the display of an advice message for the social path (in the congestion alleviation case) is shown to be more efficient than only showing additional information (in the emission reduction case).

Keywords: Advanced Urban Traffic Control, Human Behavior, Route Choice Experiment, Social Optimum, User Compliance

1 INTRODUCTION

Now that en-route navigation systems are a common feature of individual cars, Advanced Traveler Information System (ATIS) technologies can influence travelers' decisions by providing real-time travel information. This is promising to design new control policies such as route guidance (Oh et al., 2001; Angelelli et al., 2016; Wang et al., 2019). Notably, while individual-centered information can jam the network in a sub-optimal User Equilibrium (UE) state, it may also lead it towards a System Optimum (SO) if the ATIS technology is properly designed to favor system optimal routes, as shown in theoretical studies by (Dia & Panwai, 2007; Colak et al., 2016; Klein et al., 2018; van Essen et al., 2016; van Essen et al., 2019). However, one of the critical element of an efficient

route guidance system is the compliance of travelers, who may be willing to act for the common good but are faced with recommendations that go against their selfish individual goals. Understanding and estimating traveler compliance was notably done by (Kerkman et al., 2012; Djavadian et al., 2014; Ringhand & Vollrath, 2018; Klein & Ben-Elia, 2018; van Essen et al., 2018). As highlighted in these works, the compliance of travelers with social advice is higher when in-depth information is provided to them about the recommendation motivations and expected benefits, in comparison to a basic advice message. These studies also greatly contributed to the understanding of the trade-off travelers can make between their own interests and more socially desirable detours. In particular, (van Essen et al., 2018) proposed a joint regression model from a questionnaire and a field experiment with revealed choices to analyze the impact of factors such as travel time and advice contents to explain the compliance of drivers towards a social optimum.

In contrast to the existing works mentioned above, in which generally only a global measure of compliance is given, in this study we focus on the detailed quantification of compliance to better identify when users stop complying with advice due to competition with other selfish goals. We also want to observe to which extent the level of expected social benefit can counterbalance selfishness. This leads to the following research question: What is the *sacrifice* that travelers are ready to accept to improve *social welfare*? Here, we define the *sacrifice* as the relative increase of travel time a user expects to face by taking the recommended path instead of traveling on the shortest path. As for the notion of *social welfare*, we choose to focus on two major aspects: (i) the improvement of overall traffic flow (expressed as the reduction of total traveled time), and (ii) the reduction of CO₂ emissions. Our aim is to test multiple urban configurations with different origin-destination (OD) pairs and different total lengths, in order to propose a wide range of travel time sacrifices and social benefits.

2 METHODOLOGY

Our stated preference study uses a Matlab application which automatically and successively generates path choice situations for the respondent. Each path choice situation corresponds to the layout in Figure 1. Three paths, P1, P2 and P3 are proposed, whose expected travel times are such that $TT_1 < TT_2 < TT_3$. P1 is thus the shortest path (denoted by the abbreviation ShP), and it is expected to be the usual choice of users if the travel time is the only information provided. The travel time sacrifice ΔTT_j of path j is written as follows ($j = 1, 2$ or 3):

$$\Delta TT_j = \frac{TT_j - TT_1}{TT_1} \quad (1)$$

The experiment was split into four successive sessions, as presented in Table 1. The travel time information was given in all sessions. Sessions 1 and 2 referred to the first sub-question on congestion alleviation. Session 1 was the control experiment (without recommendation), and session 2 included a recommendation on either P2 or P3 for each path choice presented to the participant. The recommended path (P2 or P3) was thus explicitly defined as the social path (abbreviated by SoP). This new information was given by highlighting the social path and displaying a recommendation message with the value of the social benefit: the total traveled time (TTT in short) relative reduction ΔTTT_{red} .

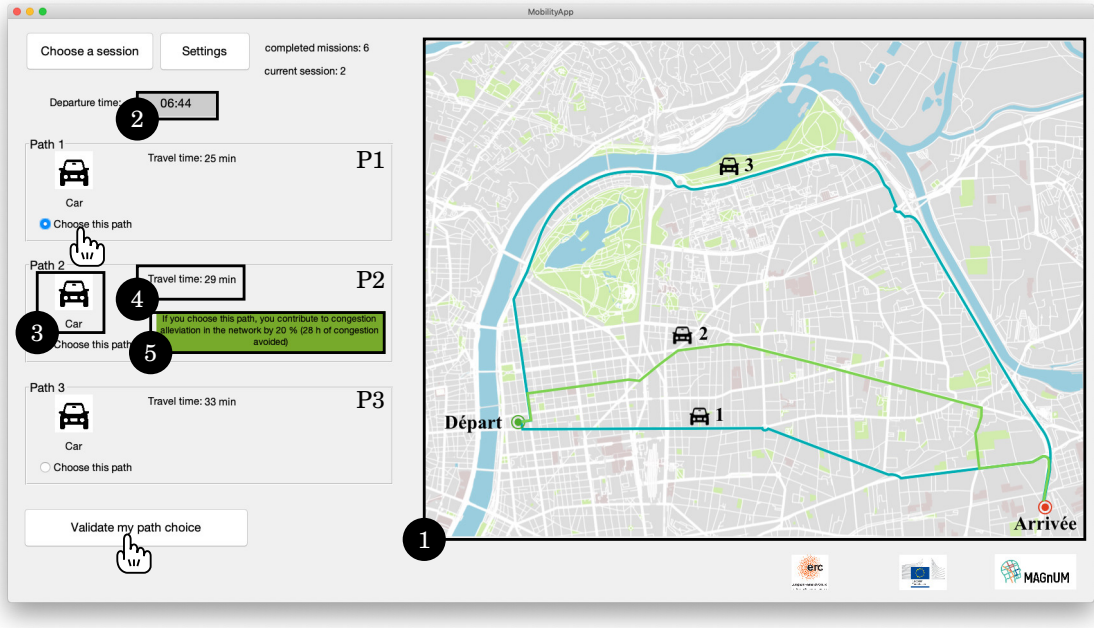


Figure 1: Screenshot of the application. A path choice situation is characterized by the following information: (1) map visualization, (2) departure time, (3) transport mode, (4) travel time and sometimes CO₂ emission, and (5) sometimes a recommendation message.

Sessions 3 and 4 referred to the second sub-question on emission reduction. Here, P3 was shown as a public transport alternative (PT in short). Session 3 was the control experiment (with only travel time information), and session 4 included the additional CO₂ emission information on all paths. As a public transport option, P3 had the lowest emission and was thus implicitly defined as the social path. In this case, the value of social benefit was defined as the relative reduction of CO₂ emission compared to the shortest path P1.

Table 1: The four sessions of the path choice experiment.

Path characteristics	Session			
	First sub-question on congestion alleviation		Second sub-question on emission reduction	
	1	2	3	4
ShP	P1	P1	P1	P1
SoP	—	P2 or P3	—	P3
PT	—	—	P3	P3
Travel time info	all paths	all paths	all paths	all paths
TTT red message	—	SoP	—	—
CO ₂ info	—	—	—	all paths

In this paper, we propose a new definition of traveler compliance. To account for the prior preferences of users (who may not be choosing the shortest path whatever the recommendation), we define the compliance as the ratio of the number of users who changed their choices for the social path between the control and recommendation experiments over the

number of users who were previously traveling on the other paths (not that which would be turned into SoP) in the control experiment. Let us suppose that p_j^0 is the proportion of users on path j during the control experiment and p_j the proportion during the recommendation experiment. Then, for the first sub-question (congestion alleviation), in the control experiment (session 1) the proportion of users traveling on possible social paths is $p_2^0 + p_3^0$ because either P2 or P3 will be turned into SoP. In the recommendation experiment (session 2), the proportion actually traveling on the social path is precisely p_j with $j = \text{SoP}$. Therefore, with our definition, the compliance κ is written as:

$$\kappa = \frac{p_{j=\text{SoP}} - p_2^0 - p_3^0}{1 - p_2^0 - p_3^0} \quad (2)$$

Similarly, for the second sub-question (emission reduction), in the control experiment (session 3) the proportion of users traveling on possible social paths is p_3^0 , as only P3 will be turned into SoP. In the recommendation experiment (session 4), the proportion actually traveling on the social path is therefore p_3 . Thus, in this case the compliance corresponds to:

$$\kappa = \frac{p_3 - p_3^0}{1 - p_3^0} \quad (3)$$

3 RESULTS AND DISCUSSION

133 participants from various ages and social backgrounds were recruited from October to December 2019. On average, each participant made 32 path choices per session, thus 128 choices for the four sessions. With all the participants, each session gathered around 4300 choice observations, thus around 17,200 observations for the four sessions. To observe the evolution of compliance in the different sessions, the choices of participants are aggregated with respect to similar intervals of sacrifice and benefit.

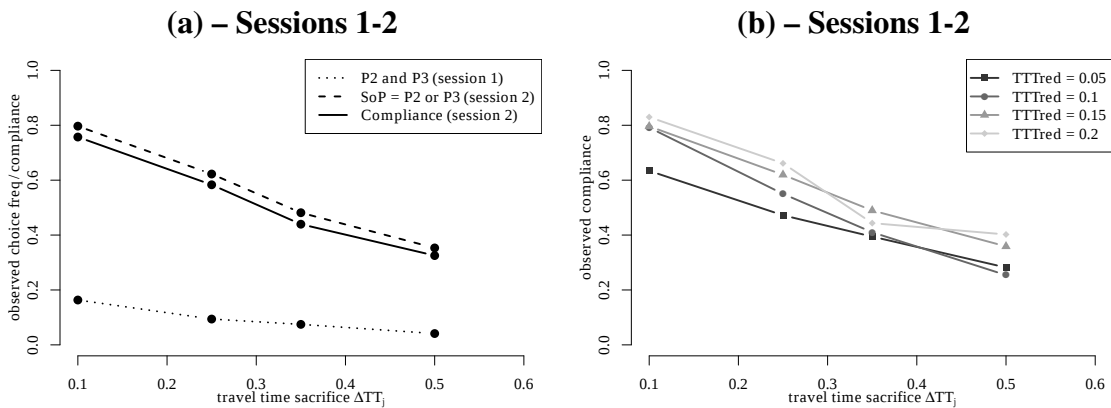


Figure 2: Compliance for the first sub-question addressed by sessions 1 and 2. (a) Global compliance for the social path ($j = \text{SoP}$), and (b) compliance by value of social benefit (relative reduction of total traveled time).

For the first sub-question on congestion alleviation, Figure 2(a) presents the compliance κ in session 2 (solid line) as calculated with the social path choice frequency in session 2 (dashed line) and the observed choice frequency of P2 and P3 in session 1 (dotted line),

see also [equation 2](#). Four values of choice frequency are calculated for four intervals of travel time sacrifice (each dot corresponds to the middle of each ΔTT_j interval). We used only four points to ensure enough observations in each travel time interval to obtain a reliable measure of choice frequency. As expected, the compliance decreases as the sacrifice increases, but several key observations are noteworthy. First, we noticed very high compliance ($\kappa \approx 0.8$) for a low sacrifice ($\Delta TT_j \approx 0.1$). This can be interpreted in the light of the Bounded Rationality theory ([Simon, 1955](#)): easily accepting a path change at a low cost may denote an indifference or satisficing behavior. Second, the decrease of compliance is surprisingly almost linear. Nevertheless, a quicker drop in compliance is visible around $\Delta TT_j = 0.3$, which may suggest a threshold where the sacrifice starts overcoming the social benefit. The compliance is reduced by half when the travel time of the social path is around 50% higher than that of the shortest path. [Figure 2\(b\)](#) depicts the same compliance evolution but now distinguished by the social benefit level displayed in the recommendation message (TTT relative reduction, ΔTTT_{red}). Overall, we observed higher compliance for a higher benefit, which was in line with expectations. However, an interesting trend is worth mentioning. For low sacrifice ($\Delta TT_j \approx 0.1$), the benefit value plays a significant role from $\Delta TTT_{\text{red}} = 0.05$ to 0.1, but is irrelevant for higher TTT reductions, meaning that the advice itself seems more important than its contents at this point. This is also the case for a sacrifice above $\Delta TT_j = 0.3$, where the benefit values of $\Delta TTT_{\text{red}} = 0.05$ to 0.1 lead to the same compliance level. However, higher values of $\Delta TTT_{\text{red}} = 0.15$ to 0.2 still have a positive effect on compliance even for high sacrifice levels. This means that only significant global gains were considered worthy by users when the sacrifice was high. The threshold here seems to be around 15% of total traveled time reduction.

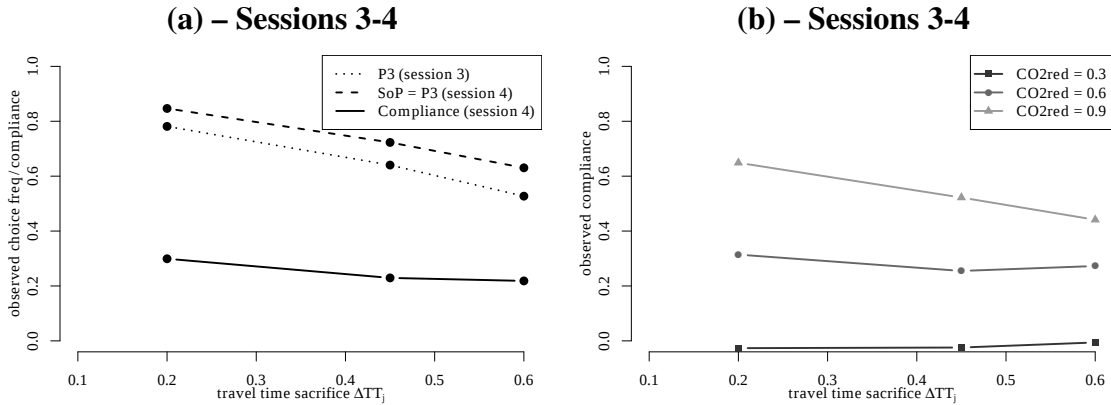


Figure 3: Compliance for the second sub-question addressed by sessions 3 and 4. (a) Global compliance for the social path ($j = \text{SoP}$), and (b) compliance by value of social benefit (relative reduction of CO₂ emissions).

For the second sub-question on emission reduction, [Figure 3\(a\)](#) presents the compliance in session 4 (solid line) as calculated with the social path (P3) choice frequency in session 4 (dashed line) and the observed choice frequency of P3 in session 3 (dotted line), see also [equation 3](#). Here only three values of choice frequency are calculated for three intervals of travel time sacrifice, due to data sampling problems in obtaining reliable estimations of choice frequency. Notable differences from the previous sub-question case can be pointed out. First, we see a clear mode preference for public transport, as suggested by the high choice frequency of P3 in session 3. Second, compliance is much lower in session 4 in

comparison to session 2, due to this mode preference. Likewise, and as expected, compliance decreases with the increase of sacrifice, but the decrease is much slower when compared to session 2. Hence, the definition of a threshold is almost impossible in this case. Putting aside the effect of mode preference, this suggests a clear difference in the perception of the social path between the two sub-questions. Whereas the effect of the advice message is immediate but rapidly decreases with travel time sacrifice in session 2, the CO₂ emission information seems less sensitive to the level of sacrifice. This perception difference is further confirmed when looking at [Figure 3\(b\)](#), which depicts the evolution of compliance in session 4 for various levels of CO₂ emission reduction (compared to the emission of P1). Unlike session 2, the effect of the social benefit value is very clear in session 4. A low relative reduction of emission has no effect (CO₂ reduction of 0.3), whereas a larger emission reduction (0.6 to 0.9) leads to an obvious increase of compliance.

4 CONCLUSIONS

In this paper, we analyzed a stated preference survey to understand and measure the competition between selfish goals and social objectives when faced with a path choice situation with recommendation. The results showed different reactions for two social objectives: (i) congestion alleviation and (ii) emission reduction. For the first one, we observed a high impact of the recommendation when the sacrifice was low, which may be explained by a satisficing behavior ([Simon, 1955](#)). Compliance then quickly drops as the sacrifice increases. The value of the congestion reduction in the advice message was found to be significant in moving travelers to the social path, albeit quite subtly. However, for the second social objective, the role of the emission reduction value was clearer: a significant reduction was required to show a significant impact on compliance. It was surprisingly less sensitive to the increase in sacrifice. Notable differences between the two cases also played a role: the social path was a public transport alternative and the recommendation was implicit by showing lower emissions for this path. In our participant set, a natural preference for public transport mode also explained the lesser effect of the emission information. This study must still be confirmed by other findings from real situations, as the stated intentions of travelers are always likely to be more optimistic than the revealed choices of the same travelers. Nevertheless, our findings could contribute to the design of route guidance policies to set thresholds of sacrifice and benefits to ensure a given level of compliance.

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