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Pre-trip information and route-choice decisions with stochastic travel conditions: Experiment

Amnon Rapoport [a,*], Eyran J. Gisches [b], Terry Daniel [c], Robin Lindsey [d]

[a] Gary Anderson Graduate School of Management, University of California Riverside, Riverside, CA 92521, USA
[b] Eller College of Management, University of Arizona, Tucson, AZ 85721, USA
[c] Alberta School of Business, University of Alberta, Edmonton, Alberta T6G 2R6, Canada
[d] Sauder School of Business, University of British Columbia, 2053 Main Mall, Vancouver, British Columbia V6T 1Z2, Canada

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ABSTRACT

This paper studies the effects of pre-trip information on route-choice decisions when travel conditions on two alternative congestible routes vary unpredictably. It presents and discusses an experiment designed to test a model recently proposed in a companion paper by Lindsey et al. (2013). That model predicts that if free-flow costs on the two routes are unequal, travel cost functions are convex, and capacities are positively and perfectly correlated, then in equilibrium, paradoxically, total expected travel costs increase with the provision of pre-trip information about travel conditions on each route. By contrast, when capacities vary independently, total expected travel costs are predicted to decrease with pre-trip information. We reformulate the model for finite populations, and then test and find support for its predictions in an experiment where under different capacity scenarios, and with and without pre-trip information, subjects are asked to choose routes with payoff contingent on their performance.

1. Introduction

Travel information has traditionally been provided by newspapers, radio, television, and variable message signs. More recently, these sources have been supplemented, or at times replaced, by Advanced Traveler Information Systems (ATIS) that compile information from various sources and convey it via traffic websites (e.g., waze.com), GPS devices, e-mail, mobile phones, and Personal Intelligent Travel Assistants. Armed with pre-trip travel information, drivers can now adjust their trip destinations and choose departure times, routes, and parking locations to minimize their cost of travel. But is this information always collectively beneficial? To answer this question, the effects of information on traffic congestion have been examined in many analytical and simulation studies; see Chorus et al. (2006) and de Palma et al. (2012) for reviews. Most of these papers conclude that information is likely to increase welfare as measured by expected social surplus, although some identify conditions under which adverse responses may occur. Our contribution is to identify some of these conditions, test them in the controlled environment of the laboratory, and discuss their implications.

The effects of pre-trip travel information on individuals' trip-making, departure time, route, and other decisions have been extensively studied. As discussed in our companion paper (Lindsey et al., 2013), several papers have identified the

* Corresponding author.
E-mail addresses: amnonr@ucr.edu (A. Rapoport), eyran@u.arizona.edu (E.J. Gisches), tdaniel@ualberta.ca (T. Daniel), Robin.Lindsey@sauder.ubc.ca (R. Lindsey).

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Notational glossary

a_{is}	free-flow travel cost on route i in state s
$A_i^j(t)$	attraction of strategy j for player i on round t in EWA model
b_{is}	congestion coefficient on route i in state s
B	bad state
$C_{is}(N_{is})$	private travel cost on route i in state s
d	power coefficient
δ	weight given to strategies not chosen in EWA model
$E[]$	expectations operator
F	full-information regime
G	good state
G^{ZF}	expected welfare gain from shifting from zero information to full information
i	index of route
$I(x, y)$	indicator function in EWA model
λ	attraction sensitivity estimator in EWA model
MSC	marginal social cost of trip
N	total number of users
N_i	number of users on route i
N_{is}	number of users on route i in state s
N_{is}^*	system-optimal number of users on route i in state s
π	probability of bad conditions on either route
π_i^j	payoff earned by player i for choosing strategy j in EWA model
r	index of information regime
R_{it}	route choice on round t by a player
$R_i^j(t)$	reinforcement that player i attaches to strategy j on round t in EWA model
s	state
S	set of states
$s_i(t)$	strategy chosen by player $i$on round t in EWA model
Z	zero-information regime

possibility that information can have adverse welfare effects. These studies employ analytical or simulation methods, but do not establish that information can actually be counterproductive in practice. In lieu of actual field studies, controlled laboratory experiments provide the best opportunity to obtain evidence of adverse information effects with human decision-makers. A number of experiments on the impact of traffic congestion have been undertaken. Mahmassani and Chang (1986), Iida et al. (1992), Mahmassani and Liu (1999), Helbing et al. (2005), Selten et al. (2004, 2007), Anderson et al. (2008), and Gisches and Rapoport (2012) investigate route-choice problems, whereas Ramadurai and Ukkusuri (2007), Ziegelmeyer et al. (2008), and Rapoport et al. (2010) examine various queueing scenarios in which agents choose when to depart on a trip. Most of these papers examine the effects of providing subjects with information about decisions and outcomes on previous rounds, but none considers the effects of providing information about travel conditions *before* subjects make their decisions.

Important exceptions are recent experimental studies by Ben-Elia and Shiftan (2010), De Moraes Ramos et al. (2011), and Ben-Elia et al. (2013) that do consider the effects of ex-ante information on route-choice decisions. However, the networks they consider are not congestible and subjects' payoffs are assumed to be independent. Lu et al. (2011) shares some features with our study, namely, route choice in a congestible network with stochastic capacity and under different information regimes. However, their experimental methods and models differ from ours: they use a small set of subjects, rewards are not contingent on performance and, most significantly, only one route in their network has stochastic travel conditions. As Lindsey et al. (2013) show, this latter difference is a key determinant of the value of ex-ante information in a network.

Still other laboratory experiments have focused on the emergence of paradoxical behavior on congested road networks. These include studies of the Braess paradox (e.g., Rapoport et al., 2009), the Pigou–Knight–Downs paradox (e.g., Dechenaux et al., 2013; Morgan et al., 2009), and queueing paradoxes in networks with bottlenecks (e.g. Daniel et al., 2009). However, none of these studies considers ex-ante information about travel conditions that vary across rounds of play. Our paper presents experimental evidence for yet another paradox, termed the *information paradox*, about the circumstances under which pre-trip information has adverse effect on route choice.

The companion paper by Lindsey et al. (2013) drives the present study. Their paper builds on the classical "two-route network" whose origins trace back to Pigou (1920) and Knight (1924). Similarly to previous studies on route choice (e.g., Selten et al., 2007), Lindsey et al. also assume a fixed set of drivers who independently choose each day which of two routes to travel. The major and critical difference from most previous studies is that the conditions of the two routes vary randomly from day to day rather than being fixed over time and commonly known. This change introduces *environmental uncertainty*, which is determined exogenously, rather than only *strategic uncertainty* that characterizes previous studies. Lindsey et al.