An experimental analysis of travel mode choice

SOSTENIBILITÀ, QUALITÀ E SICUREZZA NEI SISTEMI DI TRASPORTO E LOGISTICA

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AN EXPERIMENTAL ANALYSIS OF TRAVEL MODE CHOICE

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1. Introduction

This paper presents an experimental analysis of travel mode choice when two transport means are available. The mainstream approach to this issue assumes that travellers take decisions by maximizing individual utility and, consequently, by minimizing travel times. In contrast, psychological and cognitive studies indicate that decision-makers are limitedly rational in the activity of information processing. To investigate the implications of this theory in the laboratory, we design travel mode choice as a repeated process, in which travellers adjust their expectations for travel times on the basis of their own experience and of publicly released information.

2. Experimental design

We submitted travel mode choice to 62 subjects. Each subject was given a show-up fee of 5 euros. At the start of each session subjects received an endowment of 150 experiment tokens. At the end of the session, subjects were paid according to the tokens they held. We ran three treatments with different groups of subjects. In the first treatment, subjects had to choose between car and metro, in the second treatment between car and bus. The second and third treatments were differentiated only by the fixed cost of the bus, which changed from 1.0 to 0.8 in order to isolate *ceteris paribus* the effect of a bus price reduction.

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Tab. 1 – Sessions

Session	Treatment	Participants
1	Metro vs. Car	15
2	Metro vs. Car	15
3	Bus 1.0 vs. Car	15
4	Bus 0.8 vs. Car	17
Total		62

In each session, subjects were to choose a travel mode over 50 rounds.

Before making choices, subjects received the following information:

a) the expected travel time for each travel mode;
b) that metro expected travel time was fixed, whereas car and bus expected travel times were uncertain;
c) car and bus travel times depended on traffic congestion, as determined by subjects' travel mode choices, and on some unpredictable casual factors (weather, car accidents, road works), whose effect on travel time was randomly chosen by the computer before each round;
d) the fixed cost of each travel mode;
e) the penalty to be paid or the reward gained (0.5 token), respectively for each five minutes of delay or for each five minutes in advance of the expected or scheduled travel time.

*Tab. 2 – Experimental parameters made known to subjects**

Treatment	Car Expected Travel Time (in minutes)	Car Fixed Cost	Metro / Bus Expected Travel Time	Metro / Bus Fixed Cost
Metro vs. Car	25	1.5	30	1.0
Bus 1.0 vs. Car	27	1.5	32	1.0
Bus 0.8 vs. Car	27	1.5	32	0.8

* *Metro travel times and costs were fixed, while bus and car travel times and costs were variable.*

In each round, after making their choice each subject was privately informed of:

a) the actual (ex post) travel time of the two available modes;
b) the level of traffic congestion defined as *moderate*, *intense* or *chaotic*, related to the percentage of participants choosing the two travel modes;
c) the individual monetary cost of the journey (including additional penalties or rewards) and the remaining number of tokens.

In the metro treatment, the casual component of actual car travel time was given by a random selection from the probability distribution. The expected value of this distribution is twenty-five minutes, which was the car expected travel time made known to subjects. Actual car travel time was also dependent on traffic congestion. If the share of car users was not greater than 55%, car travel time was equal to that randomly drawn. If the share was between 55% and 75%, car travel time was increased by five minutes, while if the share was over 75%, car travel time was increased by ten minutes. Consequently, if the percentage of car users was lower than or equal to 55%, car expected travel time was twenty-five minutes and car expected cost was equal to 1.5 tokens. In this case, since subjects were informed that each five minutes of delay (ahead of time) implied a monetary loss (gain) of 0.5 token, car cost was equivalent to the metro cost of 1.0 token for a fixed travel time of thirty minutes.

In the bus treatment, the casual component of actual car travel time was determined by random selection from the probability distribution. The expected value of this distribution is twenty-seven minutes, which was the car expected travel time made known to subjects. The impact of traffic congestion on car time was determined as in the metro treatment. Thus, expected car travel time was twenty-seven minutes if the share of car users was not greater than 55%, thirty-two minutes if the share was between 55% and 75%, and thirty-seven minutes if the share was greater than 75%.

Bus travel time was also assumed to be uncertain and dependent on chance and traffic congestion. The effect of casual factors on bus time was determined by random selection from the distribution of probability. We excluded the possibility that the bus could arrive ahead of the expected time. The expected value of distribution is thirty-two minutes, which was exactly the expected time communicated to subjects.

The impact of road congestion on bus travel time was assumed to be lower than that on car travel time, which is the case if the traffic system includes routes and lanes reserved for buses. If the actual share of car users was not greater than 55%, bus travel time was equal to the value determined by the distribution of probability. Thus, traffic congestion had no impact on bus travel time if car users were less than 55% of the population. In this case, in the bus 1.0 treatment the expected bus cost was equal to 1 token for an expected travel time of thirty-two minutes, which was equivalent to the car expected cost of 1.5 tokens for an expected travel time of twenty-seven minutes. This equivalence did not hold in the bus 0.8 treatment, in which the fixed cost of the bus was decreased to 0.8.

To summarize, the parameters determining actual travel costs were as follows:

a) in the metro treatment, the expected travel costs of car and metro were equivalent if the share of car users was not greater than 55%;
b) in the bus 1.0 treatment, the expected travel costs of car and bus were equivalent if the share of car users was not greater than 55%;
c) in the bus 0.8 treatment, the expected cost of the bus was 20% lower than car expected costs if the share of car users was not greater than 55%.

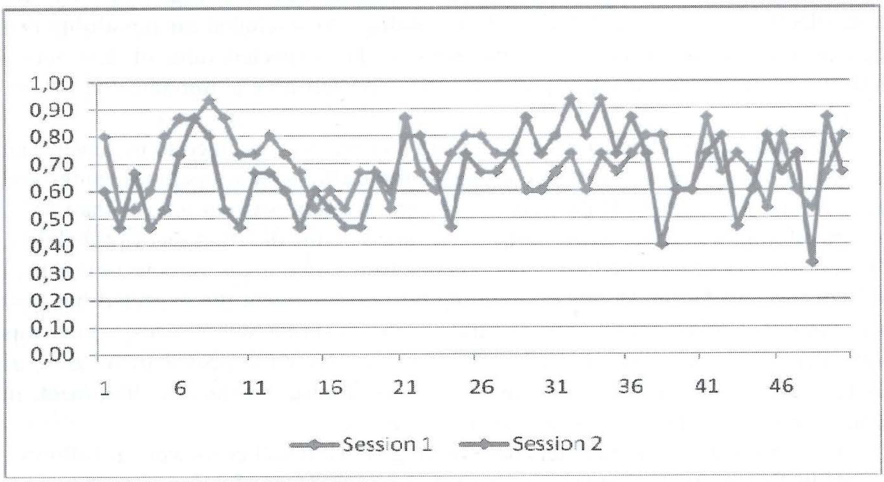
3. Results

3.1. The preference for cars

Cars are generally perceived as the means of travel which gives people a sense of freedom and independence. The costs associated with car use are frequently undervalued because they are not entirely paid simultaneously with car use. These factors explain the general propensity to use private cars, and a psychological resistance to reducing such use. Our experimental data support this observation.

In the metro treatment, the percentage of subjects choosing the car is hardly ever lower than 55%. More significantly, it is nearly the same in the first (70%) and in the last round (73%), which supports the hypothesis that choices depend more on an initial propensity to choose the car rather than on a process of learning during the experiment.

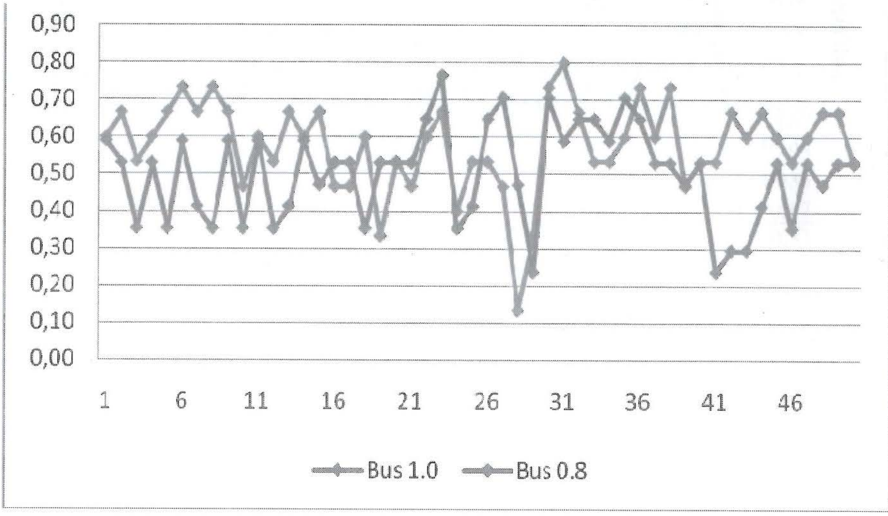
Fig. 1 – Proportion of car choices – Metro vs. Car



It is noticeable that the share of car users reaches its peak around the 7th-8th round, and then decreases for ten rounds but increases again later. Such a pattern of behaviour seems to be dependent more on behavioural inclinations acquired outside the laboratory than on context specific learning. This interpretation is confirmed by looking at expected and actual travel costs. As pointed out earlier, the probability distributions determining the effect of chance and of traffic congestion are such that car cost is higher than metro cost if the share of car users is greater than 55%. The percentage of car users is lower than the congestion threshold in only 10 rounds out of 100. The expected costs for the metro are consequently lower than expected costs for the car in the remaining 90 rounds. As far as the actual costs, determined by subjects' choices and random draws, is concerned, the average car cost over all rounds is equal to 1.46, which is greater than the fixed metro cost (1.00). Notwithstanding this comparative advantage for the metro, the ratio between car and metro users is approximately two to one.

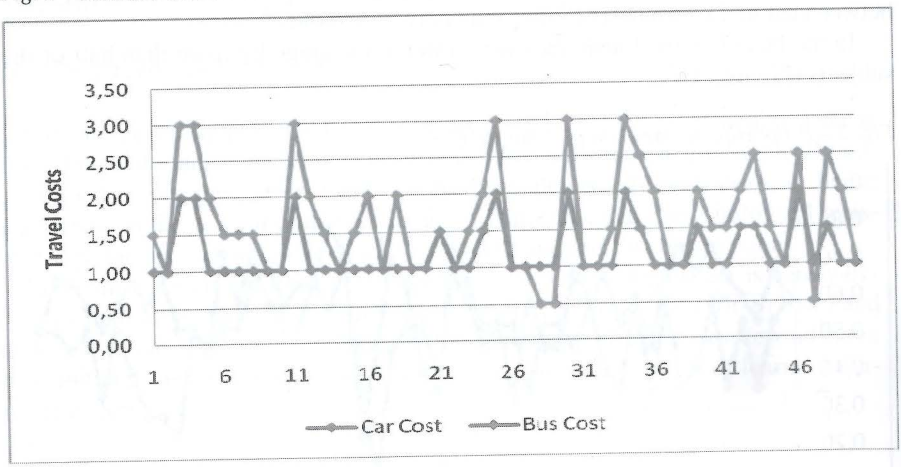
In the bus (1.0) treatment, cars are chosen on average by more than half of the subjects (Figure 2).

Fig. 2 – Proportion of car choices – Bus vs. Car



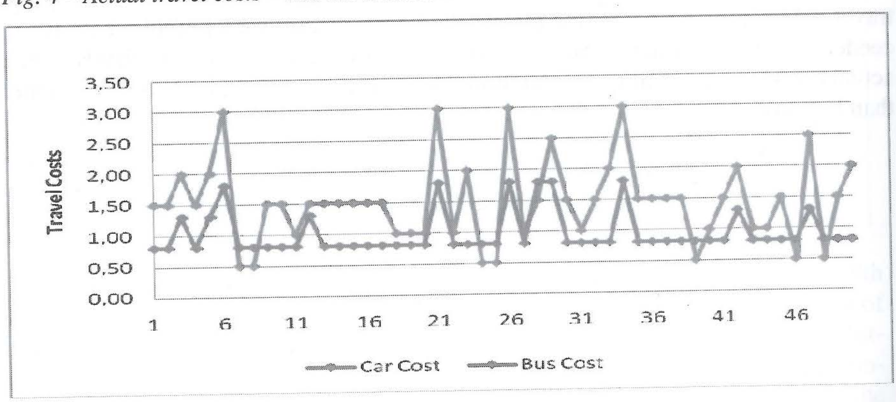
In this case too, the equivalence between expected costs of the two available travel modes remains below the threshold of 55% of car users, but this share is exceeded in 40 rounds out of 50. The preference for the car is also confirmed when actual costs are taken into consideration. On average, car cost (1.63) is 35% greater than bus costs (1.21).

Fig. 3 -- Actual travel costs -- Bus 1.0 Treatment



In the bus 0.8 treatment, the reduction of the fixed bus cost significantly increases the percentage of bus commuters, but the percentage of car users is consistently lower than half of the population only in the first twenty rounds and in half of all the sessions (Figure 2). Over all rounds, the share of car users is exactly 50%. Also in this treatment, actual costs validate the robustness of car preference, since the actual bus cost is 19% lower than actual car cost (0.96 vs. 1.48).

Fig. 4 – Actual travel costs – Bus 0.8 treatment



The dynamics of choice confirm the existence of the positive inclination towards car usage. After rounds in which car costs are very high, subjects react very quickly, but the deterrent effect does not last long.

Tab. 3 – Share of car users following very high car costs

Treatment / Session	Round	Car Cost	Share of Car Users
Metro vs. Car - Session 1	34	3.00	0.73
	35	1.50	0.67
	36	1.00	0.73
	37	1.00	0.80
	38	3.00	0.80
	39	2.50	0.60
	40	1.00	0.60
	41	1.00	0.87
Metro vs. Car – Session 2	46	2.50	0.67
	47	2.50	0.73
	48	1.00	0.33
	49	1.50	0.87
Bus 1.0 vs. Car – Session 3	25	3.00	0.53
	26	1.00	0.53
	27	1.00	0.47
	28	0.50	0.13
	29	0.50	0.33
	30	3.00	0.73
Bus 0.8 vs. Car – Session 4	6	3.00	0.59
	7	0.50	0.41
	8	0.50	0.35
	9	1.50	0.59

The share returns to the initial value only two or three rounds later. In the sequence 34-41 of Session 1, this reaction is particularly evident. After two cost peaks of 3 tokens, the share of car users drops immediately, but it goes back to higher levels after just three rounds.

Finally, it is noticeable that cars are more often chosen when the alternative travel mode is metro rather than bus ($t = 4.708$, $p < 0.05$ in the bus1.0 treatment; $t = 7.86$, $p < 0.05$ in the bus 0.8 treatment).

Tab. 4 – Frequencies of rounds by percentage and treatments (all rounds)

Proportion of car users	Car vs. Metro	Car vs. Bus 1.0	Car vs. Bus 0.8
< 0.50	10	10	20
≥0.50 < 0.60	10	11	20
≥0.60 < 0.70	34	23	5
≥0.70 < 0.80	18	5	5
≥0.80 < 0.90	25	1	-
≥ 0.90	3	-	-
Total no. of rounds	100	50	50

In the metro treatment, the share of car users is lower than 0.50 only in 10% of the rounds, while this percentage increases to 20% in the bus 1.0 treatment and to 40% in the bus 0.8 treatment.

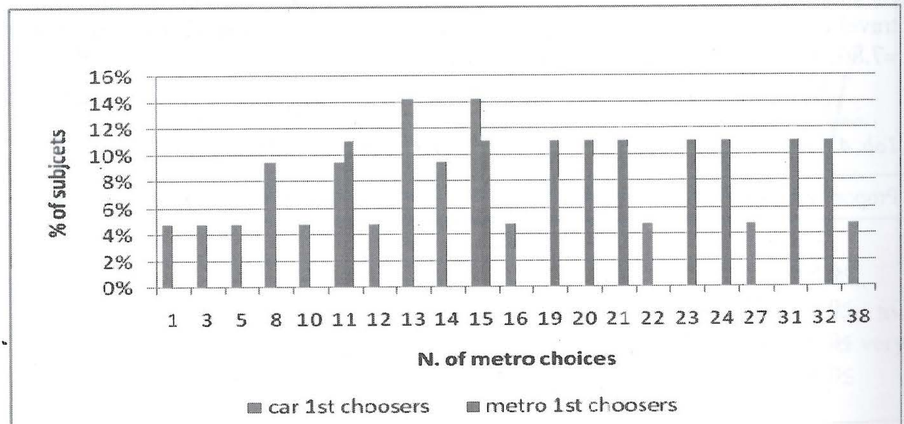
One plausible explanation for this result is given by prospect theory. According to behavioural models, in a decision framework in which only losses are possible people exhibit a risk seeking attitude. In our experiment the car would be preferred to metro because it is the riskier travel mode. This propensity would decrease in the bus treatments because both alternative travel modes are uncertain.

3.2. *The first choice effect*

Visual inspection of Figures 1 and 2 shows that the share of car users increases in the second half of each treatment and becomes less erratic in all treatments. Statistical analysis validates this impression. The average share of car users over all rounds and all treatments is almost the same: it increases from 0.57 in the first 25 rounds to 0.59 in the last 25 rounds, while the standard deviation decreases from 0.180 to 0.145. Moreover, the number of subjects changing travel mode in the last 15 rounds is a third lower than the number switching in the first 15 rounds.

These data might be interpreted as evidence of learning: subjects would gradually understand the probability distributions determining travel times and this process would decrease choice variability. On the contrary, the subjects' behaviour exhibits a significant dependence on individual first choice. Figure 5 shows the percentage of subjects by metro choice, divided into those who choose car and those who choose metro in the first round.

Fig. 5 – First choice effect – Metro Treatment



4. Concluding remarks

Our study provides laboratory evidence that commuters determine travel mode choices by using some heuristic procedures that can lead to robust deviations from travel time minimization. We find that subjects exhibit a marked preference for cars, are inclined to travel mode stickiness and, more specifically, to confirm their first choice, and adjust imperfectly expectations on travel times.

These results have relevant implications for the design of transportation policies.

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