Context-Dependent Valuation of Autonomous Shuttle Travel Time: A Stated Choice Experiment Comparing Monomodal and Intermodal Trip Contexts

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1 Introduction

When cities implement autonomous shuttles for first- and last-mile connectivity, economic assessments are predicated on the assumption that time valuations derived from isolated studies are transferable to intermodal trips. This assumption remains empirically untested, despite evidence that travelers perceive intermodal trips holistically rather than as sums of independent segments (Mackie et al., 2001; Small, 2012). Few studies have explicitly compared the value of time attributed to a given mode when evaluated in isolation versus when integrated into an intermodal trip. For autonomous shuttles, recent research suggests that their perception depends on the role they play within the overall journey rather than on their isolated characteristics alone (Thorhauge et al., 2022).

Economic evaluation and transport modelling involving automated shuttles raise an additional challenge. As these services remain relatively unfamiliar to most users and are not yet widely deployed, most studies rely on Stated Preference Surveys, with survey context playing a critical role: the way such services are described, framed, and positioned relative to competing transport modes can significantly influence respondents' stated preferences and choices (Hensher et al., 2015). This makes careful design of the experimental context essential to ensure behavioural realism and reliable model estimation.

This study examines whether the value of time for autonomous shuttles varies significantly depending on evaluation context (monomodal versus intermodal). It also aims to determine whether autonomous shuttles are perceived as an extension of public transport, as a substitute for private cars, or as a distinct mode depending on the trip configuration.

2 Literature Review

Research on intermodal trips distinguishes different time components—in-vehicle time, access/egress time, waiting time, and transfer penalties—each valued differently (Garcia-Martinez et al., 2018; Schakenbos et al., 2016). Transfers impose specific disutilities beyond time accumulation, manifesting as pure transfer penalties that affect modal choices and indicate non-linear time perception in multimodal journeys. This raises a critical question: does favourable AV time perception documented in monomodal contexts persist when AVs serve as access links within intermodal chains?

Autonomous vehicles are expected to significantly affect mobility by transforming travel time into potentially productive time. Stated preference studies show VTTS for autonomous driving decreases approximately 30% compared to conventional cars, converging toward public transport values (Kolarova et al., 2019; Steck et al., 2018). In monomodal contexts, autonomous vehicle travel time is perceived more favourably than conventional car travel.

These findings may not extend to intermodal contexts. Traditional mode choice models evaluate modes in isolation, whereas travelers perceive door-to-door journeys holistically; multimodal time values cannot be inferred from summing segments (Lenoir & Laplace, 2017). Strikingly, when autonomous vehicles serve as last-mile connections to rail transport, their in-vehicle time is perceived more negatively than manually driven cars—directly contradicting monomodal findings (Yap et al., 2016).

Despite this contradiction, research on AV–public transport integration has largely overlooked context-dependent time perception. No study has directly compared valuation contexts for the same autonomous mode, a gap this research addresses.

3 Methodology

Empirical Context

This research is carried out within the frame of the MOBAUTO2 project, which experiments autonomous shuttle deployment in the southern Paris suburbs to complement existing Bus Rapid Transit (BRT) service between Dourdan and Massy-Palaiseau, facilitating modal shift from private car to public transport.

Experimental Design

Our survey comprises two discrete choice experiments, each serving a distinct research objective. The first experiment reflects realistic intermodal trip chains for home-based journeys to other suburban areas in the outer Paris suburbs. In each choice scenario, respondents are presented with three alternatives: driving directly by car, using the car as an access mode combined with either BRT or autonomous shuttle, and using conventional bus combined with either BRT or autonomous shuttle. To reduce cognitive burden and avoid context and presentation effects associated with simultaneously introducing a new technology alongside a more familiar mode, we implemented a split-sample design in which half of the respondents evaluate scenarios with BRT as the main mode, while the other half evaluate scenarios with the autonomous shuttle. The sample is stratified according to age, income, and gender to ensure balanced representation across both experimental versions. The attributes presented vary by alternative type: the direct car option is characterized by in-vehicle time and cost, whereas intermodal alternatives (car or bus combined with BRT or shuttle) are described by access mode time, main mode time, waiting time, total cost, and crowding level. This approach allows more robust comparison of valuations between BRT and autonomous shuttles by ensuring that each mode is assessed within a consistent decision context.

In the second experiment, respondents are asked to assess the same trip, but with attention solely on the main transit segment—either BRT or an autonomous shuttle. By removing the surrounding intermodal context, these modes are presented individually, defined by factors such as in-vehicle time, waiting time, cost, crowding level, and vehicle size. This single-mode approach enables us to examine perceptions of each mode independently. Comparison of the results with the first study offers a clear basis for evaluating our core hypothesis regarding the context dependence of valuation, as well as highlighting differences in how BRT and autonomous shuttles are perceived by respondents.

Bayesian D-Efficient Design

To maximize statistical information extracted from each choice scenario while maintaining reasonable survey length, we use Bayesian D-efficient experimental designs following Bliemer and Rose (2010). Prior beliefs about parameter values are specified directionally, with all coefficients for travel time, waiting time, cost, and crowding assumed negative, reflecting their expected disutility. Design optimization, conducted in Ngene, minimizes Bayesian D-error by searching across the prior distribution to identify choice scenarios providing maximum information about parameters of interest. This procedure generated 50 choice scenarios for each experiment, subsequently organized into ten blocks of five scenarios each. Final designs achieve D-errors of 0.005 and 0.018 for the intermodal and monomodal experiments respectively, both indicating very high statistical efficiency. Each respondent is randomly assigned to one block and completes the corresponding five choice scenarios, limiting respondent burden while ensuring sufficient variation for precise parameter estimation.

Utility Specifications

For the intermodal experiment (Experiment 1), the utility of traveling by car directly is specified as:

$$V_{\text{car}} = \beta_{\text{tv,car}} \cdot \text{tv}_{\text{car}} + \beta_{\text{cost}} \cdot \text{cost} \tag{1}$$

For intermodal alternatives combining car or bus with BRT or autonomous shuttle:

$$V_{\text{car+mode}} = \text{ASC}_{\text{mode}} + \beta_{\text{tv,car}} \cdot \text{tv}_{\text{car}} + \beta_{\text{tv,mode}} \cdot \text{tv}_{\text{mode}} + \beta_{\text{tw,mode}} \cdot \text{tw}_{\text{mode}} + \beta_{\text{cost}} \cdot \text{cost} \tag{2}$$

$$V_{\text{bus+mode}} = \text{ASC}_{\text{mode,tc}} + \beta_{\text{tv,mode}} \cdot \text{tv}_{\text{mode}} + \beta_{\text{tw,mode}} \cdot \text{tw}_{\text{mode}} + \beta_{\text{tv,tc}} \cdot \text{tv}_{\text{tc}} + \beta_{\text{tw,tc}} \cdot \text{tw}_{\text{tc}} + \beta_{\text{cost}} \cdot \text{cost} \tag{3}$$

For the monomodal experiment (Experiment 2), both BRT and autonomous shuttle utilities are specified as functions of in-vehicle time, waiting time, and cost, with alternative-specific IVT and waiting time coefficients and a shared cost coefficient. An ASC is included for the autonomous shuttle:

$$V_{\text{BRT}} = \beta_{\text{tv,1}} \cdot \text{tv}_{\text{BRT}} + \beta_{\text{tw,1}} \cdot \text{tw}_{\text{BRT}} + \beta_{\text{cost}} \cdot \text{cost} \tag{4}$$

$$V_{\text{shuttle}} = \text{ASC}_{\text{SAV}} + \beta_{\text{tv,2}} \cdot \text{tv}_{\text{shuttle}} + \beta_{\text{tw,2}} \cdot \text{tw}_{\text{shuttle}} + \beta_{\text{cost}} \cdot \text{cost} \tag{5}$$

Sample Size

Following a pilot study ($N > 50$), we target a minimum sample size of 800 respondents to ensure adequate statistical power for detecting economically meaningful differences in travel time coefficients across experimental contexts and for estimating nest parameters in nested logit specifications.

4 Preliminary Results

Drawing on a panel of 56 respondents recruited through an online survey panel, we present preliminary estimates from the monomodal experiment (Experiment 2), in which participants evaluated trips served exclusively by either BRT or an autonomous shuttle. A Multinomial Logit model is estimated with in-vehicle time (IVT), waiting time, cost, and an alternative-specific constant (ASC) for the autonomous shuttle as explanatory variables.

Results (Table 1) indicate satisfactory model fit ($\rho^2 = 0{,}297$). All level-of-service attributes carry the expected negative signs and cost is the dominant determinant of choice ($\beta = -0{,}666$, $t = -8{,}01$). IVT is significant for both modes (BRT: $\beta = -0{,}084$; autonomous shuttle: $\beta = -0{,}077$), with comparable disutility for both modes. Waiting time is significant for BRT ($\beta = -0{,}164$, $t = -2{,}43$) but not for the autonomous shuttle, suggesting respondents may be less sensitive to waiting in anticipation of a more comfortable boarding experience (Thorhauge et al., 2022; Yap et al., 2016). The ASC for the autonomous shuttle is not statistically significant, indicating no baseline modal preference between the two services.

Values of travel time (VoTT) are estimated at 7,5 €/h for BRT and 7,0 €/h for the autonomous shuttle—both below standard French reference values for car travel and broadly consistent with published estimates for public transport modes (Kolarova et al., 2019; Steck et al., 2018). These preliminary results will be further examined once the full sample and the intermodal experiment data are collected.

Table 1: MNL estimates — Experiment 2, monomodal context ($N = 280$ obs., 2 alternatives)

Parameter	**Coeff.**	**Std. Err.**	***t*-stat**
Alternative-specific constant			
ASC (autonomous shuttle)	−0,613	1,276	−0,480
Level-of-service attributes			
IVT BRT (min)	−0,084	0,027	−3,061 ***
IVT autonomous shuttle (min)	−0,077	0,025	−3,116 ***
Cost (€)	−0,666	0,083	−8,005 ***
Waiting time BRT (min)	−0,164	0,068	−2,427 **
Waiting time shuttle (min)	−0,107	0,065	−1,639
Model fit			
$\mathcal{L}(\hat{\beta})$			−136,46
$\mathcal{L}(0)$			−194,08
ρ^2			0,297
Observations			280
Value of travel time			
VoTT BRT			7,5 €/h
VoTT autonomous shuttle			7,0 €/h

Significance: *** $p < 0{,}01$, ** $p < 0{,}05$, * $p < 0{,}10$.
VoTT $= |\beta_{\text{time}}/\beta_{\text{cost}}| \times 60$ [€/h].

5 Planned Analysis and Hypotheses

Hypotheses

We formulate two complementary hypotheses. First, we hypothesize that in intermodal contexts, autonomous shuttles are perceived as conventional public transport modes rather than as a distinct category and that the difference in travel time valuation is insignificant (H1). This implies that shuttles, buses, and BRT share a common preference structure and are substitutable within a public transport nest. Second, addressing our central research question, we propose that the value of travel time for autonomous shuttles is lower in intermodal contexts than in monomodal evaluations (H2). This context-dependent valuation reflects transfer penalties, cognitive coordination costs, and reduced opportunities for productive activities in fragmented multimodal trips.

Analytical Strategy

We use a sequential modeling approach. First, we estimate separate multinomial logit (MNL) models for each experiment, comparing with scaled MNL specifications to test for variance differences from our split-sample design. To test H1, we estimate nested logit models comparing alternative nesting structures where shuttles either nest with public transport modes or form an independent category. Model selection relies on log-likelihood ratio tests and information criteria. We further compare the results of the estimation for the group presented with BRT and for the group presented with autonomous shuttles. For H2, we apply the Swait–Louviere likelihood ratio test to formally assess whether σ differs significantly across experimental contexts.

6 Expected Contributions

This study is intended to improve our understanding of context-dependent time valuation, by providing the first controlled comparison of autonomous shuttle time perception across monomodal and intermodal evaluation contexts using within-sample experimental design. By testing whether favorable AV time perception documented in standalone settings extends to integrated multimodal services, it addresses a critical gap in our theoretical understanding of mode perception. Additionally, for practitioners, these findings will allow to better inform deployment strategies by providing context-specific valuation parameters, which could be used to both improve demand forecasting accuracy and the ex-ante evaluation (i.e. cost-benefit analysis) of autonomous feeder services.

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