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# Will high-speed rail compete for long-distance travel in a car-dependent society? Insights from a Canadian high-speed rail survey☆

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ABSTRACT

High-speed rail (HSR) represents a significant transport investment designed to drive economic growth and enhance long-distance regional connectivity. While HSR has demonstrated strong competitive performance against road and short-haul air travel in European and East Asian corridors, the behavioural parameters governing how HSR competes against the private vehicle in automobile-oriented North American markets, where car travel accounts for over 80% of intercity trips, remain comparatively underexamined. It is therefore less clear how travellers in such markets weigh travel time, cost, and service quality when a mature HSR alternative is introduced into a car-dominated mode share structure. The goal of this paper is to evaluate the potential for modal shift to HSR within the structural constraints of a car-dependent society. Unlike studies in transit-integrated European or Asian contexts, this study isolates the group travel penalty and car-habituation effects that characterize North American intercity travel. The study uses the Toronto-Québec City corridor in Canada, which was announced as an HSR project in 2025, to better understand if such investment can achieve its intended ridership and sustainability targets. The study analyzes data from an online bilingual long-distance travel behaviour survey (N = 6,813) conducted in October 2025. We develop a two-stage sequential weighted multinomial logit model capturing current travel behaviour and stated HSR adoption intentions. The analysis reveals that travellers are most sensitive to travel cost and travel time, with an implied value of travel time of approximately $31.5 per hour. Under a medium-adoption scenario, HSR is projected to capture 26% of corridor trips, with the largest substitution from private car and conventional rail. These findings provide an evidence-based demand projection that is essential for investment decisions while avoiding the common pitfall of ridership overestimation in large HSR projects. Practitioners can use these insights to prioritize fare-based incentives and target specific trip purposes such as business and student travel, to maximize the operational success of future HSR projects.

## 1. Introduction

High-speed rail (HSR) offers substantial travel time savings and improved service quality, which can make it a competitive option

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for intercity trips, particularly in corridors where conventional rail is not competitive with road and short-haul air travel (Cats 2025; Vickerman 2015). As HSR requires large capital investment, it is often framed as a strategic national infrastructure programme that can influence economic activity, although empirical studies report heterogeneous and context-dependent impacts across places and time (Blanquart and Koning 2017; Vickerman 2018). International practices in Europe and Asia have demonstrated the transformative potential of HSR. For instance, the Tokyo-Osaka Shinkansen and the Paris-Lyon TGV have historically achieved high ridership exceeding 100 million annual passengers (Central Japan Railway Company 2023; Farandou 2024). However, global evidence indicates that HSR projects frequently suffer from "optimism bias", with a systematic tendency for ridership estimates to be overestimated by an average of 20% to 60% compared to actual ridership in the first years of operation (Flyvbjerg 2007).

In North America, intercity passenger rail has evolved under different institutional and market conditions, which has limited the scale of "true" HSR service as defined in international practice (Peterman et al. 2012). Under the International Union of Railways speed-based definition (Leboeuf 2018), neither Amtrak's Acela on the Northeast Corridor (Boston – Washington DC) nor Brightline in Florida (Miami – Orlando) qualifies as full HSR over the bulk of its route, with the Acela approaching HSR design speeds along only a small fraction of the Northeast Corridor and Brightline operating at higher-speed conventional rather than HSR speeds. These services are nonetheless the closest operational analogues for the Canadian corridor in terms of market context and ridership benchmarking, and therefore are referenced here. California High-Speed Rail (San Francisco – Los Angeles) remains partly under construction rather than in revenue service. Ridership figures reflect the varying stages of these systems: for fiscal year 2025, the Acela reported an annual ridership of 3.2 million, which is closely similar to Brightline's observed ridership of 3.1 million (Amtrak 2025; BrightLine 2025). The California Rail Ridership Model projects that the Silicon Valley to Central Valley segment will reach an annual ridership of 12.5 million by 2050 (Db E.C.O. North America Inc. 2024).

The structural conditions underlying car dependency in the Toronto – Québec City corridor are themselves part of the empirical question this paper addresses. Comparatively low population density outside the major urban cores, post-war *peri*-urbanization, the historical absence of a dedicated passenger rail network, and decades of automobile-oriented infrastructure investment have together produced a long-distance travel market in which private vehicles account for over 80% of intercity trips. Understanding how HSR competes in such a market requires explicit attention to these spatial and infrastructural conditions alongside the behavioural parameters estimated here.

In Canada, the federal government has advanced the Toronto – Québec City HSR initiative, with early capital cost estimates in the range of \$60 – \$90 billion (Alto 2025). Project materials released under the Alto brand anticipate substantial growth in intercity rail demand, with projections of up to 24 million annual riders by 2055 (Alto 2025). It is essential to decompose this high-level projected demand to a refined-level to better understand the key drivers of HSR ridership, since ridership is used to justify such an investment. While the broader question of whether HSR can compete with road and air travel has been settled by decades of operational evidence in France, Japan, Spain, and elsewhere, the behavioural mechanisms through which HSR competes specifically against the private vehicle in automobile-oriented North American markets are less well characterized. The structural reliance on private vehicle in this region differs from the transit-integrated landscape of Europe and Asia, and the existing HSR literature offers limited empirical guidance on how travellers in such markets respond to a new HSR service when car ownership, group travel, and long-distance driving habits dominate the baseline mode share.

To address these questions, a long-distance travel survey was conducted in the Canada HSR corridor which provides revealed preference (RP) information on observed trips and stated preference (SP) information on anticipated HSR use. A two-stage sequential weighted multinomial logit (MNL) is developed which allows for analysis of how travelers value different HSR service attributes compared to existing modes. The purpose of the paper is to offer a behavioural foundation to guide HSR pricing and service design in markets without a mature rail culture, and to support the planning, management, and financial appraisal decisions that determine whether a well-managed HSR service can deliver a competitive alternative to driving and flying in such markets. The paper therefore complements, rather than questions, the established international evidence that HSR can compete effectively when implemented and managed well, and it contribute to a more realistic estimation of HSR ridership in automobile-oriented societies.

The originality of this work lies in its application of a sequential RP-SP framework to an emerging HSR corridor that lacks a mature rail culture. The international HSR literature, drawn largely from European and East Asian corridors, provides extensive evidence that HSR can compete successfully with road and air travel, but offers comparatively limited behavioural evidence from markets where private vehicle accounts for the dominant share of intercity trips and where high car ownership, path dependency, and car-habituation effects shape the baseline travel environment. Our study provides an empirical benchmark for HSR competition against the private vehicle in a market where car travel accounts for over 80% of trips. The Canadian setting also offers a rare ex ante perspective, with the model estimated before HSR enters revenue service, which complements the predominantly ex post evidence available from established HSR networks. While the magnitude of the SP-RP gap is likely mode- and context-specific, a study of the Réseau express métropolitain (REM) light rail in Greater Montréal found an approximately 4% gap between stated adoption intentions and realized first-year ridership (Balaghi et al. 2026), suggesting that well-designed SP instruments can yield behaviourally informative estimates even before a service becomes operational. This study offers a transferable framework for other automobile-oriented regions (e.g., Australia, USA) considering high-capital rail investments by examining the "optimism bias" through the lens of group-size dynamics and fare-sensitivity.

## 2. Literature review

### 2.1. HSR demand and long-distance travel mode choice

A substantial body of empirical research has examined HSR demand and mode choice using RP, SP, and joint RP − SP data across a wide range of geographic contexts. Across these studies, generalized travel cost, particularly travel time and fare, consistently emerges as the most important determinant of HSR demand (González-Savignat 2004; Hong and Najmi 2022; Román et al. 2007; Wang et al. 2014; Yao et al. 2002). Bibliometric analysis of the HSR literature confirms that travel time savings and efficiency remain the central themes of the field's evolution, though research has shifted increasingly toward assessing broader socioeconomic impacts (Chen 2023). Travel time effects are often found to dominate fare effects, especially for business travel and higher-income travellers, which reflects higher values of time (Börjesson 2014; Park and Ha 2006; Román et al. 2010). Several studies further indicate that behavioural responses to time and cost are nonlinear, with diminishing marginal sensitivity to large improvements, which suggests that simple linear utility specifications may overstate demand responses to major HSR investments (Mandel et al. 1994; Mandel et al. 1997).

Beyond in-vehicle travel time and fare, empirical studies emphasize the importance of service quality attributes and station characteristics. Frequency improvements have shown to substantially increase HSR attractiveness, particularly in corridors where total travel time differences between modes are relatively small (Hong and Najmi 2022; Pagliara et al. 2012; Yao et al. 2002). In addition to frequency, station-level attractiveness is shaped by demographic-specific demands, where different age groups prioritize distinct point-of-interest densities around the rail hub (Wu et al. 2025). Reliability and schedule convenience are frequently found to matter more for HSR than for air travel, especially when airport access time and security procedures are considered (Pagliara et al. 2012; Román et al. 2007). Socioeconomic characteristics such as income, age, and trip purpose further affect HSR demand, with systematic differences observed between business and non-business travellers and across income groups (Li and Sheng 2016; Mahardika et al. 2022; Román et al. 2010; Wang et al. 2014). The tourism sector is particularly sensitive to these HSR-driven changes in accessibility, which often leads to increased visitor numbers and longer stays at served destinations (Pagliara et al. 2017).

With respect to intermodal competition, ex post evidence indicates that the dominant source of HSR demand varies substantially across corridors and is conditioned by the prior modal balance, corridor distance and service characteristics. Synthesizing results from a range of European corridors, conventional rail has historically supplied the largest share of HSR ridership in many cases, with diversion from air and car contributing smaller and corridor-specific shares (Givoni and Dobruszkes 2013). Diversion from air has been most pronounced on long corridors with a prior dominant air share, particularly where total travel time falls below roughly 2.5 to 3 h with the Madrid − Barcelona and Paris − Lyon corridors offering well-documented examples (González-Savignat 2004; Park and Ha 2006; Román et al. 2010). In large-scale markets like China, this substitution is evidenced by significant decreases in air passenger volume, particularly on routes connecting major hubs within the 500 to 800 km range (Chen 2017). On longer corridors (approximately 500 to 800 km), HSR and air tend to coexist, with partial substitution rather than complete replacement, particularly among business travellers (Givoni and Dobruszkes 2013; Pagliara et al. 2012; Román et al. 2007). Beyond in-vehicle service attributes, terminal access and station location have been shown to play a key role in the relative competitiveness of HSR against air. Martín et al. (2014) demonstrate, in the context of the Madrid − Barcelona corridor, that access time to and egress time from terminals account for a substantial share of total generalized travel time and shape the spatial pattern of HSR's competitive advantage, with HSR retaining a strong position in central markets and air remaining competitive where airport access is comparatively favourable. While these studies emphasize passenger-side choice, recent advancements in the field have explored the strategic interaction between operators. For instance, (Shtele et al. 2025) utilize a game-theory based approach to analyze HSR and air transportation competition in a potential European corridor, which shows how operator strategies on fare and frequency reach market equilibrium. Our study complements this by providing the disaggregate behavioural foundation necessary to understand how North American travelers, specifically, would respond to such competitive service. Competition with private car travel is significant, especially on medium-distance corridors, where even modest shifts from car to HSR can generate substantial ridership gains due to the large base share of car travel in intercity markets (González-Savignat 2004; Román et al. 2010; Wang et al. 2014).

The North American position as a late adopter of HSR also raises questions that the existing literature, drawn predominantly from established European and East Asian networks, has had limited opportunity to examine. Perl and Goetz (2015) identify three strategic models for HSR development, exclusive corridors as in the Japanese Shinkansen, hybrid networks as in France and Germany, and comprehensive national networks as in China and Spain, and argue that none of these models can be transplanted directly to newcomer countries such as the U.S. and Canada because of differences in railway ownership, urban density, and intercity travel markets. A complementary line of argument, drawing on Gerschenkron (1962) suggests that late adopters may also derive advantages from skipping earlier technological generations and avoiding the path dependencies of legacy rolling stock, signalling systems, and station area land use patterns established under earlier service paradigms. The Canadian setting offers an opportunity to examine how these strategic and late-adopter considerations interact with traveller behaviour in a market without a mature rail culture.

### 2.2. RP − SP modelling in HSR demand

RP and SP data have both long been used as complementary sources in transport demand analysis, and the choice between them carries direct implications for whether a study contributes ex post or ex ante evidence on intermodal effects. RP data capture observed travel behaviour under existing market conditions and therefore reflect real constraints, habitual behaviour, and equilibrium outcomes. However, RP data are inherently limited when policy interventions or new services substantially alter the choice environment, as attribute variation is often restricted and new alternatives cannot be directly observed (Espino et al. 2006; Rashedi et al. 2017; Swait et al. 1994). SP data construct hypothetical choice scenarios with controlled variation in attributes such as travel time, cost, frequency, and service quality. SP experiments are particularly effective when identifying marginal trade-offs and willingness-to-pay measures (Cherchi and Ortúzar 2002; Swait et al. 1994). However, numerous studies have shown that SP-only models tend to overstate behavioural responses, as respondents face no real consequences and may exhibit optimism or strategic bias when evaluating hypothetical scenarios (Hensher and Li 2010; Rashedi et al. 2017). As a result, elasticities and demand forecasts derived solely from SP data may lack external validity.

Joint RP − SP analysis approaches allow stated intentions toward HSR to be interpreted relative to observed travel behaviour, combining the behavioural realism of RP data with the ability to introduce hypothetical alternatives not yet available in the market (Hensher 1997; Román et al. 2007; Yao et al. 2002). In the classical framework, a scale parameter is estimated to reconcile the difference in error variance between revealed and stated data, and both datasets are pooled into a joint likelihood, which requires that the SP instrument present respondents with a direct discrete choice among all competing modes simultaneously. Several joint RP − SP applications have incorporated stated trip frequency or expected usage as behavioural indicators, as HSR may affect not only mode choice but how often individuals travel, and when interpreted within a joint framework such frequency-based SP measures provide valuable information on latent preferences while remaining anchored to observed RP behaviour (Cascetta and Coppola 2014; Hensher 1997).

However, SP survey instruments do not always collect direct mode comparisons. When the SP question asks how often a respondent would travel if HSR were available, rather than which mode they would choose in a head-to-head comparison, the competitive trade-off needed to identify the scale parameter is absent, and a pooled joint model is not identified from such data. In this context, a sequential constrained estimation strategy provides a principled alternative: RP data are used in a first stage to anchor LOS sensitivities and existing-mode preferences, and HSR-specific parameters are then estimated in a second stage on the SP data with all RP parameters held fixed. This approach preserves the behavioural grounding of the RP estimates while still extracting information on HSR adoption from the stated responses.

At the system level, joint RP − SP models have been embedded within broader forecasting frameworks to support policy analysis and infrastructure appraisal. Applications such as California statewide HSR demand models integrate joint RP − SP mode choice components with trip generation and destination choice modules, illustrating how such approaches can support scenario testing and long-term planning without excessive model complexity (Cascetta and Coppola 2014; Outwater et al. 2010). These applications demonstrate that RP-anchored mode choice models, whether jointly or sequentially estimated, can serve as a practical middle ground between highly aggregated forecasting methods and fully disaggregate simulation approaches.

### 2.3. Challenges in HSR demand estimation

HSR demand forecasts carry structural uncertainty because they must anticipate travel behaviour under a service that reshapes generalized cost, network connectivity, and the competitive balance across modes. Evidence from international samples of transport projects shows that rail forecasts often exceed realized patronage, which implies substantial downside risk for ridership and revenue outcomes (Flyvbjerg et al. 2003; Givoni and Dobruszkes 2013). Beyond ridership risk, HSR systems can trigger complex spatial transformations and regional inequalities, the dynamics of which put further difficulty in ridership estimation (Yoo et al. 2024). The megaproject literature links this pattern to optimism bias and strategic misrepresentation, particularly where forecasts influence project selection and funding commitments (Flyvbjerg 2007).

Behavioural and market mechanisms add further complexity. A central challenge concerns the balance between diversion from


**Fig. 1.** Illustrative map of the Toronto − Québec HSR.

existing modes and induced travel: ex-post evidence suggests that HSR ridership often comes primarily from travellers who previously used other modes, while induced demand varies widely across corridors and time horizons (Givoni and Dobruszkes 2013). Forecast performance is also shaped by corridor structure, network design, and the intermodal environment (Beria et al. 2018). Overestimation tends to reflect a mix of behavioural uncertainty, corridor-specific geography and competition, and institutional incentives, which supports appraisal approaches that treat risk explicitly rather than relying on single forecast (Beria et al. 2018; Flyvbjerg 2007; Givoni and Dobruszkes 2013).

## 3. Data

### 3.1. Canadian HSR corridor-wide survey

The study uses the HSR corridor-wide bilingual survey conducted in October 2025 across the catchments of the six confirmed Alto station regions along the planned Toronto – Québec City corridor: Toronto, Peterborough, Ottawa, Montréal, Trois-Rivières, and Québec City (Fig. 1). Alto has announced seven stations in total, including Laval; Laval and Montréal are treated as a single station catchment in this study because of their proximity within the Greater Montréal area. The HSR survey is an online survey providing detailed information on respondents' current travel patterns, anticipated use and expectations of the new high–speed service, and perceived benefits and concerns of the HSR network. It includes long-distance travel history over the past 12 months covering the origin–destination (OD), travel mode, time, purpose, and size of the travel group, as well as socio-demographic characteristics such as age, gender, employment status, car ownership, and income of respondents. Recruitment targeted individuals aged 18 years and older. Digital flyers, in English or French depending on the region, were promoted via paid advertisements on Facebook and Instagram, targeting users within each region. In keeping with best practices for survey recruitment, incentives were employed to encourage participation.

Following data collection, a thorough data-cleaning procedure was applied. The cleaning process was subdivided into several sequential steps, each of which constituted a filter, reducing the number of valid responses and ensuring their validity. Respondents were excluded if they completed the survey too quickly (fastest 5%), provided invalid home or destination locations, or were associated with more than 2 IP addresses or one email address. This process resulted in a final sample of 6,813 complete and valid responses. To reduce the biases from the survey sampling and ensure the dataset remained representative of the study area's population, a weighting and expansion process was conducted. Weights were calculated to align the sample with the 2021 Statistics Canada Census population at the Census Tract (CT) level. This was achieved using the R package 'anersrake', which employs the standard iterative proportional fitting (IPF) method, also known as raking. The process utilized person-level control variables, including age, gender, and income. The resulting raking weights, which ranged from 0 to 5, were then used to compute an expansion factor. This factor was

**Table 1**
Variables and data sources.

| Variable | Description | Source |
|---|---|---|
| Mode choice | | HSR survey |
| **Car** | | |
| Travel time | Travel time in minutes average of off-peak & peak period | Google map |
| Monetary cost | Gasoline price in Canadian dollar multiplied by network travel distance (2025) | |
| **Bus** | | |
| Travel time | Scheduled travel time in minutes | Online booking provider |
| Monetary cost | Lowest one-way ticket price (2025) | busbud.com |
| Frequency | Number of departure per day | |
| **Air** | | |
| Travel time | Scheduled flight duration time in minutes | Online booking provider |
| Monetary cost | Lowest one-way ticket price (2025) | Google flights |
| Frequency | Number of departure per day | |
| **Train** | | |
| Travel time | Scheduled train travel time in minutes | VIA rail GTFS file |
| Monetary cost | Lowest one-way ticket price (2025) | VIA online booking system |
| Frequency | Number of departure per day | VIA rail GTFS file |
| **HSR** | | |
| Travel time | Prospective HSR travel time | Alto |
| Monetary cost | Willingness-to-pay in Canadian dollar (2025) | HSR survey |
| Frequency | Prospective number of departure per day | Alto |
| **Generic variables** | | |
| **Person-level** | | |
| Age | Actual age computed from the year born input | HSR survey |
| Employment status | Work full time dummy variable | |
| Income | Categorical variable with the Canadian census standard income intervals | |
| **Trip-level** | | |
| Trip purpose | Categorical variable including work/business, education/school, leisure/tourism, visiting family and friends, single-day entertainment event, healthcare, shopping, other | |
| Travel group size | Number of people travelling together for the trip | |

applied to the weights and multiplied by the Census Metropolitan Area (CMA) population to determine the total number of residents each individual sample represents in the broader population. The survey data were then converted into trip-based frame, with past trips, and prospective HSR trips for each OD being recorded with frequency and denoted with data type, which results in 20,044 rows in RP and 18,660 rows in the SP, totalling 38,704 sample size.

### 3.2. Other data sources

The variables used in this study derive from a comprehensive literature review on the influential factors on long-distance travel modal choice. As in Table 1, intercity travel time by car has been sourced through Google map, with monetary cost being sourced as the gasoline price per kilometer average of the origin and destination region, multiplied by the travel distance. For bus and air, the travel time, cost and frequency of service are sourced from online booking providers including *busbud* and *google flight*. Intercity rail travel times and frequency were derived from VIA Rail GTFS schedules. For OD pairs not served by a single scheduled train, total travel time was computed as the sum of average segment travel times via Montréal, the only transfer node in the Québec − Windsor Corridor.

The travel time and frequency were sourced from the prospective network design profile from Alto (Alto 2025), based on which a GTFS network file was developed by the TRAM group. As the stated preference of HSR usage also associates with willingness-to-pay (WTP) from the respondents, and that specific segment ticket price design is not available from Alto at the time of the study, we used the WTP to be consistent with the usage propensity condition. Later in the simulation and forecasting stage, we replaced the WTP with anticipated cost for different ticket and subsidy scenario analysis.

## 4. Methodology

### 4.1. Two-stage sequential RP-SP model specification

For ex- modelling practice, it is common practice to use behavioural information in existing travel modes from revealed preference, and incorporate stated-preference in the analysis (Román et al. 2007; Yao et al. 2002). The theoretical foundation of using multinomial logit model to estimate behavioural preference dates back to McFadden (1977), and has been broadly used and evolved in travel behaviour field. This paper develops a two-stage sequential MNL model; stage 1 estimates a standard Multinomial Logit model on observed RP trips. HSR is excluded from the choice set since it did not exist at the time of data collection. The systematic utility of mode $m \in \{car, bus, train, air\}$ is:

$$U^{RP}{}_{m} = asc_m + \beta_{tt}{}^{*}TT_m + \beta_c{}^{*}Cost_m + \beta_f{}^{*}Freq_m + \beta_m{}^{*}X + \varepsilon_m \tag{1}$$

where,

$U^{RP}{}_{m}$: the utility gained from traveling with mode $m$ reflected in the RP data;

$\beta_{tt}$, $\beta_c$, $\beta_f$: the coefficients of travel time, cost and frequency of the service;

$TT_m$, $Cost_m$, $Freq_m$: travel time, monetary cost per km and service frequency variable for mode $m$;

$\beta_m$: vector of the coefficients of the person-level or trip-level generic variables for mode $m$;

$X$: vector of the person-level and trip-level generic variables.

The utility $U$ composes of the deterministic part of utility $V$ and random error $\varepsilon$. Assuming $\varepsilon$ to follow I.I.D. Type-I Extreme Value distribution, and based on the utility specification in Equation (1), the probability function for each mode to be chosen gives:

$$P^{RP}_{m} = \frac{\exp(V^{RP}_{m})}{\sum_{m'}\exp(V^{RP}_{m'})} \tag{2}$$

The likelihood contribution of individual $i$ choosing mode $m^*$ is in Equation (2), which is used to estimation the parameters.

$$\mathscr{L}_i = \prod_{m \in M} (P_{im})^{1(m=m^*)} \tag{3}$$

Stage 2 uses the SP data, where HSR is available for all observations. All Stage 1 parameters are fixed at their estimated values. Only HSR-specific parameters are freely estimated. This constrained approach is necessary because the SP instrument elicits adoption frequency rather than a direct competitive choice among all five modes.

$$U^{SP}{}_{m} = asc_m{}' + \beta_{tt}{}'{}^{*}TT_m + \beta_c{}'{}^{*}Cost_m + \beta_f{}'{}^{*}Freq_m + \beta_m{}'{}^{*}X + \varepsilon_m \tag{4}$$

$$U^{SP}{}_{hsr} = asc_{hsr} + \beta_{tt}{}'{}^{*}TT_{hsr} + \beta_c{}'{}^{*}Cost_{hsr} + \beta_f{}'{}^{*}Freq_{hsr} + \beta_{hsr}{}^{*}X + \varepsilon_{hsr}$$

The freely estimated parameters in Stage 2 are therefore: $asc_{hsr}$ and $\beta_{hsr}$. The LOS parameters $\beta_{tt}{}'$, $\beta_c{}'$, $\beta_f{}'$ are inherited from Stage 1 and applied identically to HSR.

### 4.2. Model identification, estimation strategy, and forecasting

In the SP sample, respondents did not state an explicit preference for HSR relative to other modes. Instead, the survey asked about their potential travel frequency to major HSR stations if the service were available today. Because no direct head-to-head comparison between HSR and existing modes was elicited, the competitive trade-off required to identify the scale parameter in a classical joint RP − SP framework is absent from these data. A pooled joint model would therefore conflate the strong hypothetical appeal of a new mode, captured entirely in the HSR alternative-specific constant, with genuine behavioural sensitivity, and the scale ratio between the two datasets would be unidentified. For this reason, a classical joint RP − SP model is not estimated here.

Instead, a two-stage sequential estimation strategy is adopted. In Stage 1, a multinomial logit model is estimated on the RP data alone to recover LOS sensitivities and existing-mode preferences. These parameters reflect actual observed travel behaviour and are uncontaminated by the hypothetical framing of the SP. In Stage 2, the SP data are used to estimate HSR-specific parameters, the alternative-specific constant and sociodemographic coefficients for HSR, with all Stage 1 parameters held fixed. Respondents who indicated “Rarely/Never” for HSR on a given OD pair are treated as retaining their observed RP mode, providing the non-adoption observations against which HSR adoption is contrasted. Under this structure, the SP data contribute only to the identification of HSR-specific parameters, while the behavioural sensitivity to travel time, cost, and frequency is anchored entirely in the RP estimates.

For modal shift analysis and future mode share forecasting, the full assembled parameter set is applied to the RP microdata with HSR introduced as an available alternative. The HSR share for each OD pair is anchored under three adoption scenarios, low, medium, and high, through an OD-level calibration procedure, and forecast mode shares are predicted on the basis of the RP-estimated LOS parameters and the SP-estimated HSR preference structure.

## 5. Results

### 5.1. Descriptive analysis

The descriptive statistics for the RP and SP datasets are in Table 2. The sample provides broad coverage of both traveller sociodemographic characteristics and trip-level attributes across long-distance intercity travel. In the RP data, car travel represents the dominant mode, accounting for 71.29% of observed trips. Bus travel constitutes 13.65% of trips, followed by conventional rail at 7.69% and air travel at 7.37%. This distribution reflects the strong role of private vehicles in intercity travel within the corridor. Nearly all respondents indicated some level of willingness to use HSR in the SP data, with 97.71% reporting positive adoption intent. This pattern suggests a generally favourable perception of HSR among surveyed travellers.

At the person level, the sample has a mean age of 41.22 years, with a standard deviation of 15.54 years, which indicates representation across a wide range of working-age and older adults. Approximately 63.44% of respondents report full-time employment. Household income is skewed toward higher brackets, with 53.88% earning more than $120,000 annually, 32.53% reporting incomes between $60,000 and $120,000, and 13.55% earning less than $60,000. This distribution is consistent with the income profile typically associated with long-distance discretionary and business travel.

The survey instrument also included a multi-select question on respondents’ preferred HSR station locations, as shown in Fig. 2. Station siting is central to HSR competitiveness in car-dependent corridors, since the relative attractiveness of downtown versus

**Table 2**
Summary statistics of the data.

| Variable | *n (%); mean (SD)* | |
|---|---|---|
| **Car trips** | 35,093 | 71.29% |
| **Bus trips** | 6721 | 13.65% |
| **Train trips** | 3785 | 7.69% |
| **Air trips** | 3630 | 7.37% |
| **HSR adoption (Yes)** | 6657 | 97.71% |
| **Person level** | | |
| Age | 41.22 | 15.54 |
| Work fulltime | 4322 | 63.44% |
| Income | | |
| Less than $60 k | 923 | 13.55% |
| $60 k to $120 k | 2216 | 32.53% |
| More than $120 k | 3671 | 53.88% |
| **Trip level** | | |
| Trip purpose | | |
| Work and business | 940 | 15.42% |
| Education and school | 121 | 1.99% |
| Leisure or tourism | 2172 | 35.64% |
| Visiting family and friends | 2104 | 34.52% |
| Single day entertainment event | 447 | 14.70% |
| Healthcare | 70 | 1.15% |
| Shopping | 77 | 1.26% |
| Travel group size | 2.43 | 1.34 |

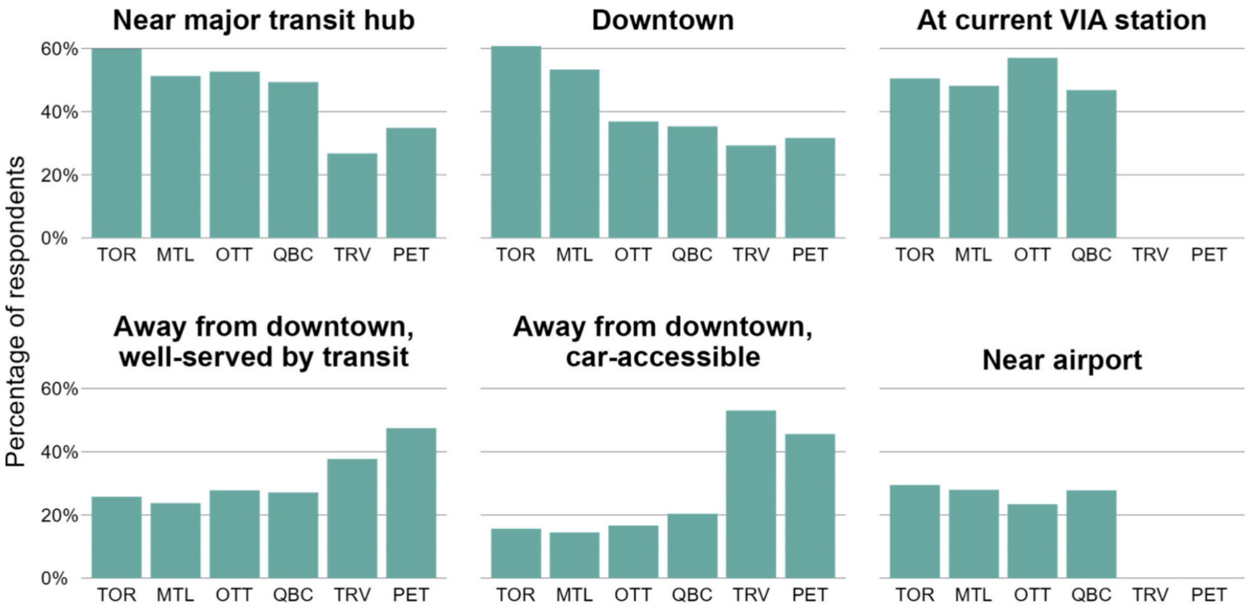


**Fig. 2.** Station location preference by the HSR announced major stops.

suburban stations depends on the spatial distribution of demand, the availability of feeder transit, and the parking and last-mile access conditions that face travellers arriving by car (Martín et al. 2014).

The pattern differs systematically between the four major cities and the two smaller intermediate cities. In Toronto and Montréal, downtown locations attract the strongest support, followed by sites near major transit hubs and the existing VIA station. Ottawa and Québec City show a similar pattern with somewhat lower downtown support but very strong preference of major transit hubs. Peterborough and Trois-Rivières, the two smaller intermediate cities, present an inverted preference structure. Car-accessible suburban sites with highway and park-and-ride provision receive the strongest support, and suburban sites well served by transit also exceed downtown support in both cities.

In the four major cities of the corridor, the combined preference for downtown locations, major transit hubs, and the existing VIA station points to a station-siting strategy that anchors HSR to the established central rail and transit nodes, broadly consistent with the European HSR experience. In the two smaller intermediate cities, by contrast, the structural reliance on car access produces a clear preference for park-and-ride-oriented suburban sites, which suggests that the corridor as a whole will need a hybrid station-siting strategy rather than a uniform model. These descriptive the station-location question provide complementary evidence on a planning dimension that the modelling results alone cannot speak to.

Trip level statistics show that the major trip purposes are leisure and family visiting. Leisure or tourism trips account for 35.64% of observations, while visiting family and friends represents 34.52%. Work and business trips comprise 15.42%, and single-day entertainment events account for 14.70%. Education, healthcare, and shopping trips together represent a relatively small share of long-distance travel. The average travel group size is 2.43 persons, with a standard deviation of 1.34, which suggests that many trips involve couples or small groups rather than solo travel.

A direct measurement on future high-speed rail ridership by OD pair is summarized in Table 3, as derived from the stated preference survey. These values represent respondents' self-reported expectations of future HSR usage and are presented as an aggregate descriptive summary rather than model-based projections. The results indicate substantial variation in expected HSR travel demand across OD pairs, with flows strongly concentrated among major metropolitan centres. Trips originating from Toronto account for the largest share of total expected boardings, with approximately 1.62 million annual trips distributed primarily toward Montréal, Ottawa, and Québec City. Among these, the Toronto – Montréal corridor shows the highest single OD volume, followed by Toronto – Ottawa and Toronto – Québec City. Montréal represents the second-largest origin, with total boardings exceeding 1.48 million. Strong bidirectional flows are observed between Montréal and Toronto, Ottawa, and Québec City, which reflects the central role of Montréal within the corridor network. Ottawa also exhibits substantial expected demand, with nearly 730,000 total boardings, largely driven by trips to and from Toronto and Montréal.

Smaller cities contribute lower absolute volumes but remain integrated into the corridor. The descriptive OD patterns suggest that anticipated HSR travel demand is highly concentrated along core intercity pairs while still supporting connectivity across the broader corridor. These stated frequencies provide an empirical benchmark for subsequent modelling exercises, which examine how service attributes and traveller characteristics shape future HSR adoption and modal competition.

Fig. 3 presents the RP mode shares for each OD pair, which reflect observed mode preference under current service conditions. The figure illustrates substantial heterogeneity in modal composition across OD pairs, driven by distance, service availability, and relative competitiveness of modes.

**Table 3**
Weighted prospective annual ridership from direct measurement of stated preference.

| Station | TOR | PET | OTT | MTL | TRV | QBC | Boarding |
|---|---|---|---|---|---|---|---|
| TOR | | 267,884 | 389,300 | 568,678 | 105,754 | 288,519 | 1,620,134 |
| PET | 60,040 | | 12,620 | 9,316 | 2,841 | 5,392 | 90,209 |
| OTT | 269,977 | 23,541 | | 322,088 | 28,201 | 85,858 | 729,665 |
| MTL | 394,653 | 25,399 | 438,785 | | 167,521 | 451,112 | 1,477,471 |
| TRV | 7,898 | 1,035 | 7,016 | 41,362 | | 32,403 | 89,713 |
| QBC | 47,981 | 13,550 | 52,872 | 130,504 | 45,602 | | 290,509 |
| Total | | | | | | | 4,297,701 |

* the stations are abbreviations for Toronto, Peterborough, Ottawa-Gatineau, Montréal, Trois-Rivieres, Québec City, respectively; same abbreviations are used from here.

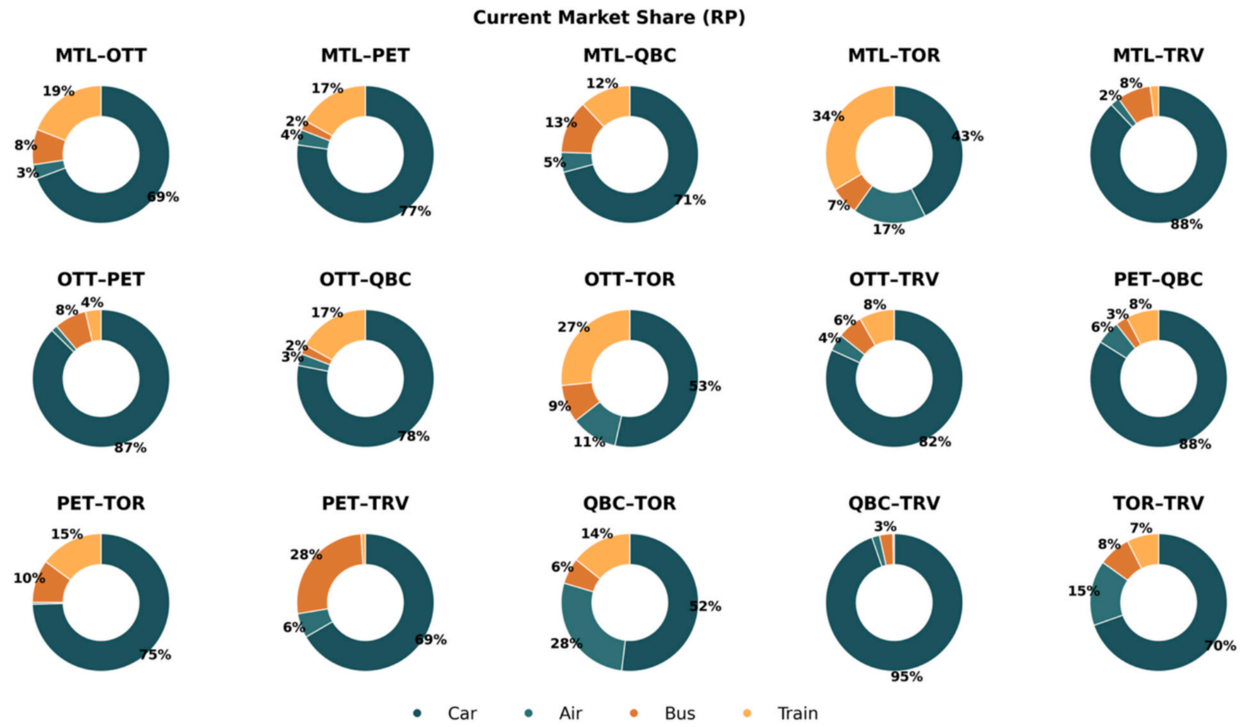


**Fig. 3.** Travel mode share from revealed-preference data by OD.

Across most OD pairs, car travel remains the dominant mode, particularly for shorter and medium-distance markets. OD pairs such as Toronto – Peterborough, Montréal – Trois-Rivières, Ottawa – Peterborough, and Québec City – Trois-Rivières show a strong reliance on private vehicles, with car mode shares exceeding three quarters of total trips in several cases. These patterns are consistent with limited rail service frequency, shorter travel distances, and greater flexibility associated with car travel in these markets.

For longer-distance and high-demand corridors, modal shares become more balanced. The Toronto – Montréal and Toronto – Ottawa pairs exhibit meaningful shares for rail and air travel alongside car use. Rail holds a substantial presence in these corridors, reflecting established intercity rail services and relatively competitive travel times. Air travel is primarily concentrated in the longest OD pairs (Toronto and Québec City) where it captures a noticeable share of the market despite airport access and processing time.

### *5.2. Sequential RP-SP MNL model estimation results*

The estimation results are presented in Table 4, with car specified as the reference alternative. All Stage 1 parameters are estimated on the RP data; Stage 2 estimates only the three HSR-specific parameters with all Stage 1 values held fixed. The coefficients for travel cost and travel time are negative and statistically significant, confirming strong sensitivity to generalized cost in long-distance travel. The implied value of travel time (VoT) is $31.5 per hour, which aligns closely with the national average hourly wage for salaried employment in Canada, currently sits at approximately $36.8 per hour (Statistics Canada 2025). This indicates that intercity travelers value their time at a rate close to their gross earnings, and that time savings carry meaningful welfare and market competitiveness implications for intercity services. The value of time is consistent with international HSR benchmarks. For instance, studies on the

**Table 4**
Two-stage sequential estimation results.

| Parameter | Stage 1: RP Model | Stage 2: SP Model |
|---|---|---|
| **Alternative-specific constants** | | |
| ASC_bus | −0.519 (0.123)*** | *Fixed* |
| ASC_train | −0.186 (0.073)** | *Fixed* |
| ASC_air | −0.561 (0.118)*** | *Fixed* |
| ASC_HSR | — | 3.314 (0.051)*** |
| **LOS coefficients (generic, all non-car modes)** | | |
| Travel time (per min) | −0.00200 (0.000208)*** | *Fixed* |
| Travel cost (per $1) | −0.00381 (0.000204)*** | *Fixed* |
| Service frequency (per dep./day) | 0.00192 (0.00307) | *Fixed* |
| **Sociodemographic coefficients — Bus** | | |
| Age | −0.0165 (0.00199)*** | *Fixed* |
| Full-time employed | −0.425 (0.061)*** | *Fixed* |
| High income | −0.237 (0.061)*** | *Fixed* |
| Work / education trip | 0.348 (0.073)*** | *Fixed* |
| Leisure trip | −0.188 (0.066)*** | *Fixed* |
| Party size | −0.042 (0.022) | *Fixed* |
| **Sociodemographic coefficients — Train** | | |
| Full-time employed | −0.069 (0.048) | *Fixed* |
| High income | 0.238 (0.046)*** | *Fixed* |
| Work / education trip | 0.309 (0.056)*** | *Fixed* |
| Leisure trip | −0.169 (0.050)*** | *Fixed* |
| Party size | −0.131 (0.017)*** | *Fixed* |
| **Sociodemographic coefficients — Air** | | |
| Full-time employed | 0.087 (0.068) | *Fixed* |
| High income | 0.703 (0.064)*** | *Fixed* |
| Work / education trip | 0.718 (0.070)*** | *Fixed* |
| Leisure trip | 0.065 (0.068) | *Fixed* |
| Party size | −0.054 (0.021)** | *Fixed* |
| **Sociodemographic coefficients — HSR** | | |
| Full-time employed | — | 0.025 (0.058) |
| High income | — | 0.003 (0.057) |
| **Model fit statistics** | | |
| *Init.* log-*likelihood* | −21,794.0 | |
| *Final* log-*likelihood* | −15,216.6 | |
| *Rho-squared* | 0.302 | |
| *Adjusted rho-squared* | 0.301 | |
| *AIC* | 30,477.1 | |
| *BIC* | 30,649.5 | |

Significance codes: *** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$ † $p < 0.10$ (blank) not significant.
'Fixed' indicates the parameter was estimated in Stage 1 and held constant during Stage 2 estimation.
'—' indicates the parameter does not enter the utility function for that stage.

Spanish AVE network and the California HSR project utilize income-stratified discrete choice models to derive travelers' willingness to pay for time savings (Outwater et al. 2010; Román et al. 2010). Our results confirm that even in car-dependent North American corridors, intercity travelers exhibit a high valuation of time savings comparable to these established and proposed HSR markets. Service frequency carries a positive coefficient consistent with a preference for greater service availability, but does not reach statistical significance in the RP sample and should be interpreted cautiously in policy simulations.

Relative to car, air travel has a lower baseline utility as reflected by a negative and statistically significant constant. However, air is strongly and positively associated with higher income, full-time employment, and work- or education-related travel, indicating that air serves travellers with higher time values and more time-constrained schedules. Group size reduces the probability of choosing air, consistent with the cost burden of purchasing multiple tickets, while leisure purpose shows a small and statistically weak association. Bus also has a lower baseline utility than car and shows strong negative associations with age, full-time employment, and higher income, indicating that bus use is concentrated among younger travellers and those with greater budget sensitivity. Bus remains more common for work- or education-related trips, while leisure travel is negatively associated, consistent with lower attractiveness for discretionary long-distance journeys. Conventional rail has a smaller baseline penalty than bus or air, suggesting a more competitive position relative to car. Rail is positively associated with higher income and work- or education-related trips, while leisure travel and larger party sizes are negatively associated, with the group size effect being particularly pronounced.

HSR carries a very large and statistically significant positive constant (3.314), reflecting the strong hypothetical appeal captured by the SP instrument. This magnitude is notably larger than the constants for any existing mode and warrants interpretive caution: it likely absorbs both genuine HSR preference and the optimistic framing inherent in adoption-intent survey questions, suggesting that the forecast mode shares should be treated as an upper-bound scenario conditional on a mature and well-known service rather than a short-run ridership projection. The sequential estimation strategy adopted here partially mitigates this risk by anchoring the LOS sensitivities and the existing mode constants to the RP data, so that the SP component contributes only the HSR specific parameters rather than driving the overall behavioural structure of the model. The reported simulation results should therefore be read as sensitivity analyses anchored to revealed corridor behaviour rather than as standalone SP-based ridership forecasts. The HSR-specific sociodemographic parameters for employment status and income are not statistically significant, indicating that once LOS attributes and the baseline HSR preference are controlled for, these characteristics do not further differentiate HSR adopters in the SP sample. The Stage 1 RP model achieves an adjusted rho-squared of 0.301, indicating a strong fit and systematic behavioural segmentation by income, trip purpose, employment status, and group size alongside the core LOS effects.

### 5.3. Elasticities

The average marginal effects are reported in Table 5, which quantify the change in predicted mode choice probability associated with a one-unit increase in each explanatory variable, holding all other variables at their sample means. Two scaling conventions are used: LOS and HSR-specific sociodemographic effects are multiplied by $10^{-3}$, and RP sociodemographic effects are expressed in percentage points ($\times 10^{-2}$).

For LOS variables, the Stage 1 RP marginal effects confirm that travel time and cost reduce the probability of choosing each non-car mode, while service frequency increases it, consistent with standard expectations for long-distance mode choice. The magnitudes are small at the margin, indicating that unit changes in these attributes shift predicted shares modestly, though their cumulative effect across realistic policy-relevant ranges can be substantial. The corresponding Stage 2 SP marginal effects follow the same directional pattern but are considerably smaller in absolute magnitude across the four existing modes, with the HSR column absorbing the majority of the LOS response. A one-minute increase in HSR travel time reduces HSR probability by $0.127 \times 10^{-3}$, and a one-dollar increase in HSR cost reduces it by $0.242 \times 10^{-3}$. The frequency effect on HSR is $0.122 \times 10^{-3}$, directionally consistent but reflecting the non-significant frequency coefficient transferred from Stage 1.

The RP sociodemographic marginal effects show clearer and larger differentiation across scheduled modes. A shift to work- or education-related travel increases the probabilities of conventional rail (+4.290 pp), air (+5.767 pp), and bus (+2.756 pp), consistent with higher time pressure and stronger preference for scheduled services among commuters and students. Leisure travel shows the opposite pattern, reducing bus (−1.492 pp) and rail (−2.340 pp) probabilities, while the effect on air is small and positive, likely reflecting holiday air travel. An additional person in the travel party reduces rail probability most substantially (−1.819 pp), with smaller reductions for bus and air, consistent with the cost and convenience advantages of private vehicles as group size grows. Higher income increases rail and air probabilities and reduces bus probability, reflecting the stronger valuation of time among higher-income travellers. Age reduces bus probability and has no meaningful effect on rail or air, suggesting that older travellers shift away from bus specifically rather than from scheduled modes in general.

The Stage 2 HSR-specific sociodemographic marginal effects for employment status and income are very small, $1.576 \times 10^{-3}$ and $0.178 \times 10^{-3}$ respectively on HSR probability, and neither is statistically significant, indicating that once LOS attributes and the baseline HSR preference are accounted for, these characteristics do not further differentiate HSR adopters in the SP sample. The HSR marginal effects overall should be interpreted as preference responses within the SP adoption framing rather than fully revealed behavioural responses under real-world operating conditions, given that the cost attribute reflects WTP rather than an observed market fare and that the SP instrument captures hypothetical rather than actual competitive choices.

### 5.4. Market shares

To examine potential changes in intercity travel patterns once HSR becomes operational, future mode shares were simulated using the estimated two-stage sequential model. The simulations are designed to illustrate how mode substitution varies across OD pairs under different levels of HSR adoption, rather than to generate point forecasts.

Three HSR adoption scenarios were defined (low, medium, and high)[1] by anchoring the aggregate HSR mode share for each OD pair to externally specified targets derived from the existing mode share structure. Conditional on these anchors, the estimated behavioural parameters were applied to simulate the redistribution of trips across all competing modes for each OD pair through an OD-level bisection calibration procedure. This structure ensures that the simulated outcomes reflect revealed sensitivities to travel time, cost, service frequency, and trip characteristics while remaining anchored to plausible adoption bounds.

Fig. 4 presents the simulated mode shares under the medium-adoption scenario. Several systematic patterns emerge across the 15 bi-directional OD pairs. Car remains the dominant mode in virtually all corridors even after HSR introduction, which reflects the strong baseline car preference estimated from the RP data. The most substantial HSR shares appear in long-distance corridors that currently exhibit meaningful rail or air usage. In the Montréal – Toronto corridor, HSR captures 44% of trips, drawing primarily from the existing conventional rail and air markets. The Québec City – Toronto and Ottawa – Toronto corridors show HSR shares of 34% and 33% respectively, again with the largest substitution effects concentrated in the rail and air segments. These projected shares represent a fundamental expansion of the scheduled-mode market through the direct substitution of car trips, a finding that aligns with behavioural forecasts for other emerging HSR markets in automobile-oriented societies, such as the California High-Speed Rail project (Outwater et al. 2010). While these substitution rates are more conservative than the 40–60% shifts observed in center-to-center

[1] Under the medium scenario, train share is fully absorbed into HSR, 60% of air share migrates to HSR, and 3% of combined car and bus share shifts, subject to an overall cap of 60%. The low scenario applies more conservative diversion fractions (30% of air, 1% of road modes, cap of 50%), while the high scenario allows more aggressive substitution (85% of air, 6% of road modes, cap of 70%).

**Table 5**
Average marginal effect.

| | Stage 1 — RP Model | | | | Stage 2 — SP Model | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Car** | **Bus** | **Train** | **Air** | **Car** | **Bus** | **Train** | **Air** | **HSR** |
| **LOS** *($\times 10^{-1}$ percentage points)* | | | | | | | | | |
| TT (per min) | — | −0.158 | −0.277 | −0.161 | — | −0.012 | −0.035 | −0.016 | −0.127 |
| Cost (per $1) | — | −0.301 | −0.528 | −0.305 | — | −0.023 | −0.066 | −0.030 | −0.242 |
| Frequency (per + 1) | — | 0.152 | 0.267 | 0.154 | — | 0.011 | 0.033 | 0.015 | 0.122 |
| **Sociodemographic — Stage 1 RP sample** *(percentage points)* | | | | | | | | | |
| Work / education trip | — | 2.756 | 4.290 | 5.767 | — | — | — | — | — |
| Leisure trip | — | −1.492 | −2.340 | 0.521 | — | — | — | — | — |
| Party size | — | −0.335 | −1.819 | −0.437 | — | — | — | — | — |
| Age | — | −0.131 | 0.000 | 0.000 | — | — | — | — | — |
| High income | — | −1.877 | 3.304 | 5.641 | — | — | — | — | — |
| Full-time employed | — | −3.364 | −0.951 | 0.695 | — | — | — | — | — |
| **Sociodemographic — Stage 2 HSR-specific (SP sample)** *($\times 10^{-3}$)* | | | | | | | | | |
| Full-time employed | — | — | — | — | −1.576 | — | — | — | 1.576 |
| High income | — | — | — | — | −0.178 | — | — | — | 0.178 |

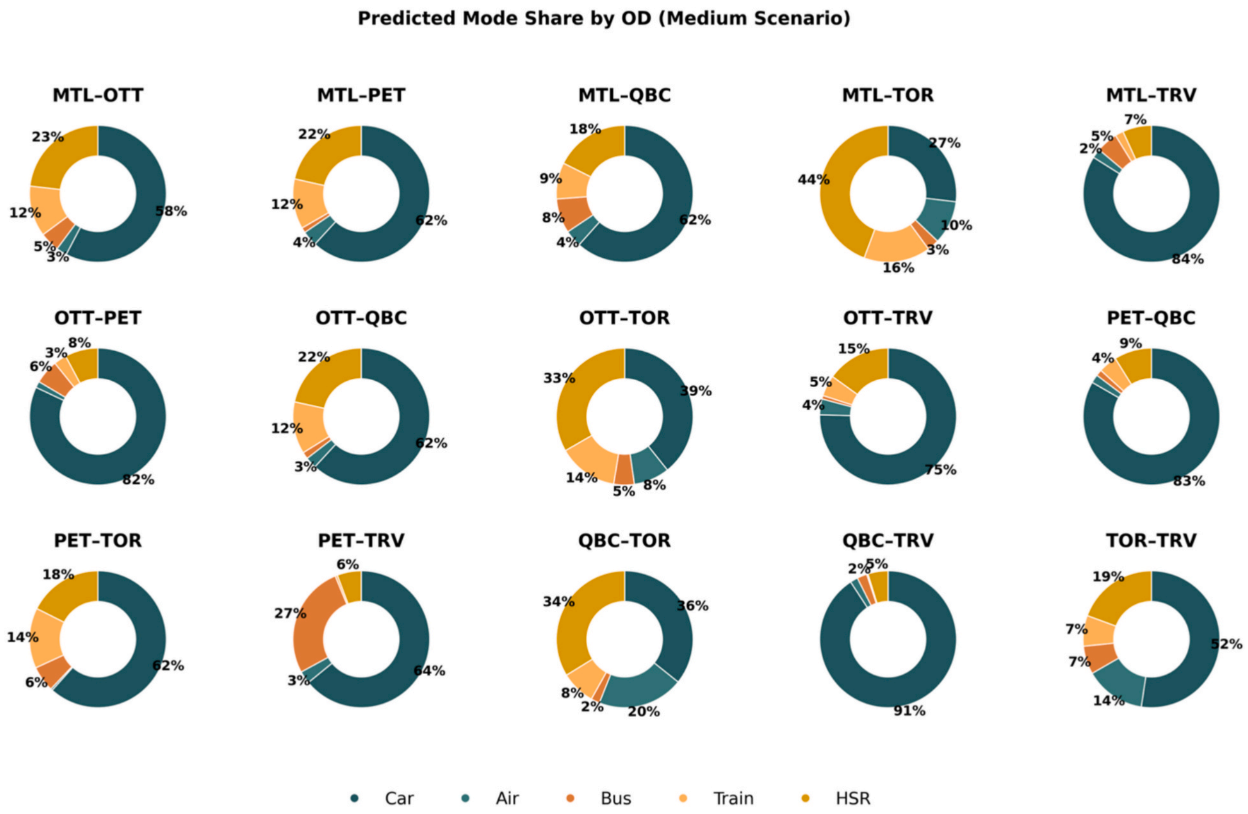


**Fig. 4.** Simulated market share by OD (medium-HSR adoption scenario).

European corridors like Madrid – Barcelona (Román et al. 2010), the results confirm that HSR can successfully penetrate intercity markets even where structural car dependency is high.

By contrast, shorter-distance and more car-dominated corridors show considerably more limited HSR uptake. Pairs such as Ottawa – Peterborough (8% HSR), Montréal – Trois-Rivières (7%), and Québec City – Trois-Rivières (5%) retain very high car shares, 82%, 84%, and 91% respectively, even under the medium scenario. In these markets HSR substitution is modest and draws largely from bus and conventional rail rather than from private vehicles, reflecting the difficulty of attracting car-dependent travellers to a new fixed-route service on shorter journeys where the car's door-to-door convenience advantage is strongest.

The Peterborough – Trois-Rivières corridor stands out as an exception, with a relatively high bus share (27%) persisting alongside a modest HSR share (6%), which likely reflects the absence of strong air or rail alternatives on that pair and limited trip volumes to redistribute.

Comparison across OD pairs indicate that HSR primarily reshapes markets where public transport and air already play a significant role, while its influence on strongly car-oriented corridors remains limited. These findings reinforce the importance of corridor-level analysis when assessing future HSR ridership and investment outcomes, and caution against applying aggregate corridor forecasts uniformly across OD pairs with structurally different travel patterns.

### 5.5. Scenario-based analysis

To assess how policy interventions may influence future intercity travel patterns once HSR is operational, a set of scenario-based simulations was conducted using the estimated sequential RP − SP model. The scenarios focus on two policy levers that are commonly considered in HSR planning: improvements in LOS and fare subsidies. All scenarios are evaluated relative to a business-as-usual (BAU) case, which reflects the introduction of HSR under baseline service and pricing assumptions. Table 6 reports the predicted market shares across all modes under each scenario. The RP mode shares are shown for reference, while the future mode shares reflect simulated outcomes after HSR introduction.

Scenario 2 evaluates the effect of a 50% increase in HSR service frequency. Relative to the BAU, HSR share increases modestly from 25.86% to 26.19%, a gain of 0.33 percentage points. The diversion is distributed across all existing modes, with car experiencing the largest absolute reduction (−0.19 pp), followed by train (−0.07 pp), air (−0.04 pp), and bus (−0.03 pp). While the directional effect is consistent with the positive frequency coefficient estimated in Stage 1, the magnitude is notably small, which reflects the non-significant frequency parameter transferred from the RP model. This result suggests that service frequency improvements alone, even of substantial magnitude, produce limited aggregate modal shift given the weak behavioural sensitivity to frequency identified in the RP data.

Scenario 3 evaluates the effect of a 50% reduction in HSR fares. This produces a considerably larger response: HSR share increases from 25.86% to 27.83%, a gain of 1.97 percentage points — approximately six times the effect of the frequency improvement. Car experiences the largest diversion (−1.05 pp), followed by train (−0.49 pp), air (−0.28 pp), and bus (−0.15 pp). The relatively larger response to fare reduction is consistent with the statistically significant and precisely estimated cost coefficient in Stage 1, which implies stronger and more reliable sensitivity to price than to frequency in this corridor.

The two scenarios indicate that fare reductions generate substantially larger modal shift toward HSR than equivalent proportional improvements in service frequency under the current model estimates. This finding contrasts with the conventional planning assumption that service quality improvements are the primary lever for attracting ridership and reflects the specific pattern of behavioural sensitivity identified in the RP data from this corridor. This emphasis on pricing over frequency aligns with recent bibliometric trends suggesting a shift toward assessing HSR through the lens of long-term financial sustainability and economic efficiency (Chen 2023).However, two important caveats apply. First, the frequency coefficient is not statistically significant, so the Scenario 2 effect should be interpreted with considerable caution. In some contexts, frequency and service quality are highly dependent on demographic-specific demands; for instance, younger and older travelers may prioritize different station-area amenities over raw service frequency (Wu et al. 2025). Second, the HSR cost variable is based on willingness-to-pay rather than an observed market fare, which means the Scenario 3 magnitude may not translate directly to the response that would be observed under actual pricing conditions. Both scenarios are best understood as sensitivity analyses that illustrate the direction and relative scale of these policy levers rather than precise ridership forecasts. A separate but related question concerns the effect of exogenous shifts in the cost of car and air travel arising from broader macroeconomic and geopolitical conditions. Recent disruptions to North American vehicle manufacturing arrangements and to global oil markets suggest that the real cost of driving and flying may rise materially over the coming decade,. The estimated cost coefficient in Stage 1 provides a direct behavioural lens on this question: a sustained increase in car generalized cost of the order of 20–25%, holding HSR fares constant, would produce a modal shift toward HSR of comparable magnitude to the fare reduction effect reported in Scenario 3. A similar logic applies to elevated air fares, with the magnitude of the shift scaled by the smaller baseline air share. A second category of dynamics concerns the strategic response of incumbent air and conventional rail operators following HSR entry. Ex-post evidence from European corridors indicates that incumbent air carriers typically reduce fares on directly affected OD pairs in the year after HSR launch, and that conventional rail operators adjust fares to retain market position. These

**Table 6**
Simulated demand responses to potential policy levers.

| Policy scenarios | Predicted market share RP | | | | Future | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Car (%) | Bus (%) | Train (%) | Air (%) | Car (%) | Bus (%) | Train (%) | Air (%) | HSR (%) |
| *Scenario 1:* BAU | 71.29 | 13.65 | 7.69 | 7.37 | 53.19 | 4.46 | 11.13 | 5.36 | 25.86 |
| *Scenario 2:* Improvement of LOS 50% higher service frequency | | | | | 53.0 | 4.43 | 11.05 | 5.32 | 26.19 |
| *Scenario 3:* HSR fare subsidies 50% lower ticket price[2] | | | | | 52.14 | 4.31 | 10.64 | 5.08 | 27.83 |

[2]As the specific fare structure was unavailable at the time of this study, willingness-to-pay is utilized as a proxy; consequently, the resulting economic interpretations should be approached with caution

responses act in the opposite direction to HSR-side policy levers and would partially offset the modal shift estimated in Scenarios 2 and 3. Recent work using game-theoretic frameworks has begun to model the equilibrium outcomes of such operator interactions (Shtele et al. 2025). An elevated cost scenario combined with a treatment of incumbent competitive response, represents a productive direction for follow up work and would allow HSR competitiveness to be assessed under a wider range of plausible future operating environments.

## 6. Conclusion

This paper develops a two-stage sequential multinomial logit model of long-distance mode choice along the Toronto – Québec City corridor, achieving an adjusted rho-square of 0.301 on the RP sample and revealing several behavioural insights that address the critical need for more realistic ridership estimation in emerging HSR markets. Travellers are considerably sensitive to travel cost and travel time at the margin, with an implied value of travel time of approximately $31.50 per hour, while conditioned on trip purpose and travel party size. Service frequency is retained in the model but does not reach statistical significance in the RP sample which suggests that frequency-based policy simulations must be interpreted with caution in regions where structural car dependency remains the primary barrier. The findings show that while HSR exhibits a significant positive baseline utility across sociodemographic groups, the per-person pricing structure of scheduled rail remains a major structural disadvantage compared to private vehicles as group size increases. Our results quantify the specific behavioural barriers that HSR must overcome in car-dependent societies. Addressing this through innovative fare structure is necessary for HSR to compte with private vehicle in North America markets.

From an international planning perspective, these results provide the empirical basis for mitigating “optimism bias” in HSR forecasting. The mode share simulations demonstrate significant spatial heterogeneity of demand, with modal substitution concentrated in high-density corridors where air and conventional rail are already established. Conversely, the limited shift in shorter-distance, car-dominated segments suggests that national corridor planning must move beyond aggregate ridership figures to account for local spatial dynamics and regional restructuring. The behavioural patterns reported here are consistent with the structural causes of car dependency in the Canadian corridor, including comparatively low population density outside the major urban cores, post-war *peri*-urbanization, the absence of a dedicated passenger rail network, and decades of automobile-oriented infrastructure investment. The strong group-size penalty estimated for scheduled modes, and the persistence of high car shares on shorter and medium-distance OD pairs even after HSR introduction, both reflect this structural inheritance. The descriptive evidence on station-location preferences further indicates that the corridor will likely require a hybrid station-siting strategy rather than a uniform model: major cities show strongest support for downtown and transit hub locations, while the two smaller cities show preference for car accessible suburban sites. In the major cities, well-connected suburban sites with high transit and car access may offer a better balance than downtown siting, given the land costs, congestion, and limited value-capture potential associated with already built-out urban cores. These findings point to differentiated, last-mile-sensitive station design along the corridor rather than a single siting model applied uniformly. The policy scenario analysis further suggests that in emerging HSR systems, strategic pricing interventions and financing models may generate larger initial modal shifts than service-level investments alone.

The findings carry clear implications for HSR governance and institutional arrangements. The study suggests that federal funding frameworks and regulatory designs should adopt conservative baseline demand scenarios. This is particularly vital in North American and other car-dependent contexts to avoid the systematic overestimation of ridership observed in international practice. Furthermore, addressing the “group travel penalty” through innovative fare structures or multi-modal integration emerges as a necessary strategy for HSR to compete with the private vehicle in leisure-oriented markets.

Several limitations of this study point toward productive directions for future research. The classical joint RP – SP framework was not applied here because the SP instrument elicits hypothetical HSR adoption frequency rather than a direct discrete choice among competing modes, which precludes identification of the scale parameter needed for joint estimation. Future survey designs that incorporate explicit head-to-head comparisons between HSR and existing modes would support a fully joint model and yield more precise estimates of HSR preference relative to alternatives. The MNL specification assumes independence of irrelevant alternatives, which may not fully capture substitution dynamics between closely related alternatives such as conventional rail and HSR; nested logit, mixed logit, or latent class frameworks could relax this assumption and accommodate unobserved preference heterogeneity across traveller segments. One limitation concerns the temporal gap between data collection and HSR operation. The corridor population will shift through births, deaths, migration, and changes in household structure over the pre-operational period, and the demographic composition of the sample reported here will not exactly match the population using HSR once the service enters revenue operation. The behavioural parameters estimated in this paper, including the value of travel time, cost sensitivities, and group-size effects, tend to be considerably more stable across cohorts than demographic distributions, and they can be combined with updated population projections at the forecast stage to produce ridership estimates calibrated to the corridor population at the time of operation. A further limitation concerns the alignment of the corridor itself. The detailed route between Peterborough and Ottawa, and the question of whether intermediate centres such as Kingston, Belleville, Brockville, will be served, has not been finalized at the time of this study. The behavioural parameters estimated here are anchored to the six confirmed station regions and are therefore not affected by this uncertainty, but corridor-level ridership projections, and local service provision will need to be revisited once the final alignment and any additional intermediate stops are announced. Future work could employ new forms of mobility data to better assess how HSR-induced accessibility changes influence labour market integration and firm location along the corridor. A complementary direction would be to construct counterfactual scenarios that compare current intercity travel patterns and mode shares against alternative trajectories in which HSR had been adopted in North America at a pace closer to that of European or East Asian markets, which would allow the trade-offs between late-adopter advantages and the long-term costs of sustained automobile dependency to be assessed directly. Finally, connecting behavioural demand modeling with HSR station-oriented development and land value capture mechanisms represents a necessary extension to ensure the long-term financial sustainability and regional development potential of large-scale infrastructure investments in automobile-oriented societies.

## CRediT authorship contribution statement

**Yu Zhang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Ahmed El-Geneidy:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

The data that has been used is confidential.

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