

Analysis Of The Impact Of Seamless Transportation On Airport Passenger Mode Choice: A Quantitative Study Of Airport Train Services

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Abstract

Seamless transportation is increasingly important for improving airport accessibility, yet the mechanisms through which multimodal integration shapes passengers' transportation choices remain insufficiently understood. This study develops an integrated framework to examine the relationship between seamless transportation and airport passenger mode choice, focusing on the mediating roles of perceived convenience and perceived reliability. Drawing on discrete choice theory and the hybrid choice modelling framework, the study conceptualizes seamless transportation through physical, temporal, informational, and ticketing integration. The proposed Hybrid Choice Model (HCM) integrates passengers' latent perceptions with observed travel attributes, including travel time, travel cost, waiting time, and access distance, to explain

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the relative utility of airport rail compared with competing ground transportation alternatives. The framework further specifies direct and indirect pathways through which seamless transportation may influence mode choice. Methodologically, the study proposes a quantitative explanatory design using passenger survey data and, where feasible, revealed-preference and stated-preference observations. The proposed analysis evaluates measurement quality, structural relationships, mediation effects, and discrete choice model performance. The framework contributes to transportation research by distinguishing convenience from reliability as complementary behavioral mechanisms and by integrating these perceptions into a utility-based choice model. From a managerial perspective, it highlights the importance of coordinated transfers, integrated passenger information, interoperable ticketing, and dependable service operations alongside competitive travel times and costs. The framework provides a basis for evaluating passenger-oriented airport access strategies and informing multimodal transport planning. Its empirical conclusions, however, require validation using observed passenger data and an appropriately estimated HCM.

Keywords: Seamless transportation; airport access mode choice; Hybrid Choice Model; multimodal integration; perceived convenience; perceived reliability; airport rail.

INTRODUCTION

The integration of railway services with airport transportation systems has become an important component of contemporary transport planning, particularly as airports seek to improve ground accessibility, reduce dependence on private vehicles, and provide more efficient passenger journeys. Airport rail services offer an alternative to road-based transportation by connecting airports with urban Centre's and other transport networks. However, the availability of an airport railway does not necessarily guarantee that passengers will select rail as their preferred access mode. Their decisions may also depend on the accessibility of stations, transfer distances, waiting times, service reliability, ticketing arrangements, and the availability of clear travel information. Previous research on airport ground access has demonstrated that travel time, travel cost, reliability, service quality, and passenger characteristics are important determinants of mode choice (Tam et al., 2011; Airport Access Mode Choice, 2022). These findings suggest that the attractiveness of airport rail should be evaluated not only through the



performance of the railway service itself but also through the quality of the overall journey connecting passengers to the airport.

In this context, the concept of seamless transportation provides a relevant perspective for understanding how passengers evaluate integrated transport services. Seamless transportation refers to the extent to which a journey involving multiple transport modes can be completed with minimal physical, temporal, informational, and transactional barriers. Physical integration concerns the ease of transferring between transport modes and facilities; temporal integration relates to schedule coordination and waiting times; information integration concerns the availability, clarity, and consistency of travel information; and ticketing integration involves the convenience of purchasing and using tickets across connected services. Grotenhuis et al. (2007) demonstrated that integrated multimodal travel information can help passengers reduce the time and effort required to plan and undertake public transport journeys. Their research highlights the importance of information provision throughout different stages of a trip, including pre-trip planning, transfers, and travel on board. Accordingly, seamless transportation can be understood as a passenger-oriented characteristic of the transport system that extends beyond the operational performance of individual.

The relevance of seamless transportation becomes particularly apparent in airport access journeys, where passengers often face strict arrival-time requirements and may carry luggage or travel with companions. Even when an airport train offers competitive in-vehicle travel time, passengers may prefer a taxi, private vehicle, or ride-hailing service if reaching the station requires complicated transfers or if connecting services are perceived as uncertain. Conversely, well-coordinated connections, reliable information, convenient ticketing, and accessible terminal facilities may strengthen the attractiveness of rail-based airport access. Research by Tam et al. (2011) incorporated perceived service quality and travel-time reliability into airport ground access mode-choice modelling, demonstrating the relevance of subjective service evaluations alongside conventional travel attributes. Similarly, research examining airport access at Milan-Bergamo Airport found that passengers' choices were sensitive to travel-time components and costs, and that changes in rail service provision could affect the distribution of airport access modes (Cascetta & Carteni, 2014). These studies provide a foundation for examining how the perceived continuity of the entire journey may contribute to passengers' decisions to use airport rail.



Mode choice is commonly analyzed using discrete-choice models grounded in random utility theory. Under this framework, traveler's select the alternative that provides the highest perceived utility among the available options, with utility determined by observed attributes and an unobserved component (Ben-Akiva & Lerman, 1985; Train, 2009). For airport access, observed attributes may include travel time, travel cost, waiting time, access distance, and passenger characteristics such as income, travel purpose, and frequency of airport use. Although these variables provide an important explanation of transport decisions, they may not fully capture the psychological mechanisms through which passengers evaluate integrated journeys. For example, two passengers facing similar travel times and fares may make different choices because they perceive the ease of transferring between modes or the reliability of connecting services differently. Consequently, incorporating latent perceptions into mode-choice analysis may provide a more comprehensive understanding of airport passenger behavior.

The Hybrid Choice Model (HCM) offers a methodological approach for addressing this limitation by integrating discrete-choice modelling with latent psychological constructs and their measurement indicators. HCMs extend conventional choice models by explicitly incorporating perceptions, attitudes, and other latent variables into the explanation of individual choices (Ben-Akiva et al., 2002). In the present study, seamless transportation is conceptualized as the principal explanatory construct, represented through physical, temporal, informational, and ticketing integration. Perceived convenience and perceived reliability are proposed as mediating constructs that may explain how the perceived quality of transport integration translates into mode-choice decisions. The model also incorporates observed attributes, including travel time, travel cost, waiting time, access distance, and relevant passenger characteristics. By combining these elements, the proposed framework can distinguish the contribution of perceived journey integration from the effects of conventional travel attributes within a unified behavioral model.

Despite the relevance of multimodal integration and airport access mode-choice research, an important analytical opportunity remains in examining seamless transportation as a multidimensional, passenger-perceived construct within an integrated choice model. Previous studies have examined integrated travel information, perceived service quality, travel-time reliability, and airport access mode choice, but these strands of research do not necessarily capture all four dimensions of seamlessness within a single framework. The present study therefore seeks to connect the perceived integration of physical facilities, schedules, information, and ticketing with airport passengers' mode-choice decisions, while examining the potential



mediating roles of perceived convenience and perceived reliability. This proposed contribution should be understood as a research gap to be tested through a systematic review of the relevant literature, rather than as a claim that no previous study has investigated these relationships.

Against this background, this study aims to analyze the influence of seamless transportation on airport passenger mode choice, with particular attention to airport rail services. Specifically, it examines whether perceived seamless transportation is associated with perceived convenience and perceived reliability, whether these perceptions contribute to the utility of choosing airport rail, and whether seamless transportation also has a direct relationship with mode choice after accounting for observed travel attributes. The study adopts a quantitative design and proposes a Hybrid Choice Model that integrates latent-variable measurement with discrete-choice estimation. Its expected theoretical contribution is to extend the application of integrated choice and latent-variable modelling to passenger-perceived multimodal integration. Its practical contribution is to provide an evidence-based framework for airport authorities, railway operators, and transport planners to identify which aspects of integration may deserve priority in improving airport accessibility and the competitiveness of airport rail services.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The following section continues the previously drafted Introduction and develops the theoretical arguments and hypotheses for the study. The literature is grounded in research on multimodal transport information, airport access mode choice, service convenience, and integrated choice and latent-variable models.

Seamless Transportation and Multimodal Integration

Seamless transportation represents a passenger-oriented approach to transport integration in which the quality of a journey is evaluated across the entire travel chain rather than through the performance of individual transport modes. In multimodal journeys, passengers may encounter barriers associated with physical transfers, schedule coordination, information availability, and ticketing arrangements. These barriers can increase the time and effort required to complete a journey, potentially reducing the attractiveness of public transportation alternatives. Grotenhuis et al. (2007) demonstrated that integrated multimodal travel information is relevant to passengers' travel decisions because it can reduce travel-planning effort and support coordination across different stages of a journey. Their findings provide a



foundation for understanding seamlessness as a combination of operational coordination and the passenger's ability to navigate the transport system efficiently.

In the context of airport rail services, seamless transportation can be conceptualized through four interrelated dimensions. Physical integration refers to the accessibility and ease of transferring between transport modes, stations, and airport terminals. Temporal integration concerns the coordination of schedules, waiting times, and connections. Information integration captures the availability, clarity, and consistency of journey information before and during travel. Ticketing integration concerns the ease of purchasing, validating, and paying for connected transport services. These dimensions form the proposed operational framework for measuring perceived seamless transportation in this study. They should be empirically validated to determine whether they function as distinct dimensions or as components of a higher-order construct.

Airport access research reinforces the importance of evaluating the journey as a whole. Tam et al. (2011) incorporated perceived service quality and travel-time reliability into airport ground-access mode-choice modelling, demonstrating the relevance of subjective service evaluations alongside conventional travel attributes. Their study provides a direct empirical foundation for examining airport access decisions beyond travel time and cost alone.

Nevertheless, seamless transportation should not automatically be treated as synonymous with service quality or convenience. Service quality is a broader evaluation of service performance, whereas seamless transportation focuses specifically on the continuity and coordination of the journey across modes and service interfaces. Perceived convenience, in turn, represents an individual's evaluation of the effort and practicality involved in completing that journey. Distinguishing these concepts enables the proposed model to examine whether seamless integration contributes to convenience and reliability, and whether those perceptions help explain airport passenger mode choice.

Seamless Transportation and Perceived Convenience

Perceived convenience refers to the extent to which passengers consider a transport journey easy, practical, and relatively free from unnecessary effort. Berry et al. (2002) conceptualized service convenience in terms of the time and effort consumers must expend when obtaining and using a service. Although their framework was developed in service research rather



than specifically for airport rail, it provides a useful theoretical basis for explaining why simplified transport arrangements may improve passengers' evaluations of a journey.

Seamless transportation is expected to improve perceived convenience because physical, temporal, informational, and ticketing integration can reduce the effort involved in transferring between modes. For example, a clearly signposted connection between an airport railway station and terminal can reduce the effort required to navigate the transfer. Coordinated schedules can reduce waiting, while integrated information can help passengers plan their journeys with greater confidence. Similarly, convenient ticketing arrangements can reduce the number of transactions needed to complete a multimodal trip. Grotenhuis et al. (2007) support the broader proposition that integrated multimodal information can reduce passengers' time and effort requirements.

In airport transportation, these benefits may be particularly important because passengers often travel with luggage, accompany other travelers, or face time constraints associated with flight departures. A journey that requires several poorly coordinated transfers may be perceived as inconvenient even when its railway segment is fast. Conversely, an integrated journey may be perceived as practical when the connections are easy to understand and complete. Accordingly, the following hypothesis is proposed:

H1: Perceived seamless transportation positively influences perceived convenience among airport passengers.

Seamless Transportation and Perceived Reliability

Perceived reliability concerns passengers' confidence that a journey can be completed predictably and that connecting services will operate in a sufficiently coordinated manner. In airport access, reliability is important because an unexpected delay can increase the risk of arriving late for check-in, security screening, or boarding. Reliability therefore extends beyond the punctuality of a single transport mode to include passengers' expectations regarding the continuity of the overall journey.

Tam et al. (2011) examined the role of travel-time reliability in airport ground-access mode choice and incorporated perceived service quality into a discrete-choice framework. Their research demonstrates that reliability-related perceptions can be relevant to airport access decisions and that the effects of service attributes can be evaluated through mode-choice modelling.



Seamless transportation may strengthen perceived reliability by reducing uncertainty at transfer points. Accurate information about connecting services, predictable waiting times, and coordinated schedules can help passengers anticipate the progress of their journeys. Clear information can also make service disruptions easier to understand and manage. However, seamlessness does not necessarily guarantee operational punctuality; the proposed relationship concerns passengers' perceptions of journey reliability and must be distinguished from objectively measured on-time performance. Based on this reasoning, the following hypothesis is proposed:

H2: Perceived seamless transportation positively influences perceived reliability among airport passengers.

Perceived Convenience and Airport Passenger Mode Choice

Perceived convenience may influence mode choice because passengers generally evaluate transport alternatives in terms of the time, effort, and practical difficulties associated with completing a journey. In the service literature, convenience reflects the resources consumers must expend to access and use a service (Berry et al., 2002). In airport transportation, this evaluation may include the ease of reaching a station, the simplicity of transferring between modes, the accessibility of terminal facilities, and the effort required to purchase tickets or obtain travel information.

An airport railway may offer competitive travel time and cost, but passengers may still prefer taxis, private vehicles, or ride-hailing services if these alternatives provide more convenient door-to-door access. Conversely, when railway connections are easy to navigate and require fewer transfer-related efforts, the perceived utility of airport rail may increase. This relationship should be evaluated alongside observed travel attributes because convenience may be correlated with travel time, access distance, and waiting time.

The relevance of subjective service evaluations to airport access decisions is supported by Tam et al. (2011), who incorporated perceived service quality into a mode-choice model for airport ground access. In addition, the integrated choice framework allows latent perceptions to contribute to the utility of transport alternatives alongside observable characteristics (Ben-Akiva et al., 2002). Therefore, the study proposes the following hypothesis:

H3: Perceived convenience positively influences the utility of choosing airport rail, controlling for observed travel attributes.



Perceived Reliability and Airport Passenger Mode Choice

Perceived reliability is another potential determinant of airport passenger mode choice. Unlike convenience, which emphasizes the effort required to complete a journey, reliability concerns the predictability of that journey and the passenger's confidence in reaching the airport within an acceptable time. These considerations are particularly important when passengers face fixed flight schedules and have limited flexibility to accommodate delays.

Tam et al. (2011) found that travel-time reliability and perceived service quality were relevant to airport ground-access mode-choice modelling. Their study illustrates the value of incorporating reliability-related perceptions into an analytical framework that also considers conventional transport attributes.

For airport rail, reliable connections and clear information may increase passengers' confidence in the complete journey. However, the effect of perceived reliability on mode choice is not necessarily independent of travel time, fare, or the availability of alternatives. A passenger may still select a private vehicle despite recognizing the reliability of rail if the private vehicle offers a substantially shorter door-to-door journey. The proposed model therefore evaluates perceived reliability as one component of alternative-specific utility rather than assuming it determines the choice by itself. Accordingly, the following hypothesis is proposed:

H4: Perceived reliability positively influences the utility of choosing airport rail, controlling for observed travel attributes.

The Direct Relationship between Seamless Transportation and Mode Choice

Seamless transportation may also influence airport passenger mode choice independently of its potential effects on perceived convenience and perceived reliability. Physical connections, integrated information, coordinated schedules, and convenient ticketing can reduce the practical barriers associated with multimodal travel. These improvements may increase the relative attractiveness of airport rail even after accounting for passengers' general perceptions of convenience and reliability.

Discrete-choice theory explains transport decisions through the comparison of utilities associated with available alternatives. The utility of each alternative can incorporate measurable attributes and, where appropriately specified, latent perceptions (Ben-Akiva & Lerman, 1985; Train, 2009). In this study, seamless transportation is proposed as a latent explanatory construct that may contribute to the utility of airport rail relative to competing modes.



The proposed direct relationship is important because the effect of seamlessness may not be fully captured by convenience and reliability. For instance, integrated ticketing may simplify the purchasing process even when passengers do not report a substantial change in their overall perceptions of journey convenience. Similarly, better information integration may reduce the complexity of navigating different operators and services.

Nevertheless, the direct effect must be distinguished from the indirect effects operating through the proposed mediators. Its empirical significance will depend on the estimated model and the measurement properties of the constructs. Therefore, the following hypothesis is proposed:

H5: Perceived seamless transportation positively influences the utility of choosing airport rail, after accounting for perceived convenience, perceived reliability, and observed travel attributes.

The Mediating Roles of Perceived Convenience and Perceived Reliability

The preceding arguments suggest that seamless transportation may influence airport passenger mode choice through both direct and indirect pathways. The mediating role of perceived convenience reflects the possibility that integrated transport services reduce the effort required to complete an airport-access journey, thereby increasing the relative utility of airport rail. The mediating role of perceived reliability reflects the possibility that coordinated connections and accessible travel information strengthen passengers' confidence in the predictability of the journey.

The use of mediation pathways is consistent with the broader logic of integrated choice and latent-variable modelling, which enables researchers to incorporate perceptions into explanations of observed choices rather than relying exclusively on measurable travel attributes (Ben-Akiva et al., 2002). Evidence from airport ground-access research also supports examining perceived service quality and reliability within the same choice framework (Tam et al., 2011). However, the specific indirect effects proposed here require empirical testing; they cannot be assumed from the existence of transport integration alone. The study therefore proposes two mediation hypotheses:

H6: Perceived convenience mediates the relationship between perceived seamless transportation and the utility of choosing airport rail.

H7: Perceived reliability mediates the relationship between perceived seamless transportation and the utility of choosing airport rail.



These hypotheses will be examined within the Hybrid Choice Model by estimating the latent-variable relationships and their contribution to alternative-specific utility. The analysis should distinguish the direct effect of seamless transportation from the indirect effects through convenience and reliability. Because the dependent variable is categorical, mediation should be evaluated using the estimated choice model rather than relying exclusively on conventional linear regression procedures.

Observed Travel Attributes and the Hybrid Choice Model

Although passenger perceptions are central to the proposed framework, airport mode choice is also influenced by objective journey characteristics. Travel time, monetary cost, waiting time, and access distance affect the resources passengers must expend to reach an airport. Discrete-choice theory provides an established basis for incorporating these attributes into the utility functions of competing transport alternatives (Ben-Akiva & Lerman, 1985; Train, 2009).

For example, a lower fare may increase the attractiveness of a railway alternative, whereas a long access journey or substantial waiting time may reduce its relative utility. The effects may vary across passenger groups and travel contexts. Passengers travelling for business, passengers carrying substantial luggage, and passengers travelling with family members may assign different importance to time, cost, and transfer conditions. These differences justify the inclusion of passenger characteristics and trip context in the empirical model.

The Hybrid Choice Model is appropriate because it integrates observed attributes with latent perceptions and their measurement indicators. Ben-Akiva et al. (2002) discuss the progress and challenges of hybrid choice modelling, including the incorporation of psychological constructs into discrete-choice analysis. Research on airport-choice behavior has also demonstrated the potential of HCMs to capture psychological factors and improve model fit relative to conventional choice models in a particular empirical setting. The following hypothesis concerns the observed travel attributes:

H8: More favorable travel attributes, including lower travel time, lower travel cost, shorter waiting time, and shorter access distance, increase the utility of the relevant transport alternative, all else being equal.

This hypothesis will be operationalized through alternative-specific utility coefficients. The expected directions should be evaluated against the final coding and specification of each



attribute. Passenger characteristics will initially be treated as explanatory or control variables unless a specific theoretical argument supports additional hypotheses.

RESEARCH METHODOLOGY

Research Design

This study adopts a quantitative explanatory research design to examine the relationship between seamless transportation and airport passenger mode choice, with particular emphasis on the roles of perceived convenience and perceived reliability. The research focuses on airport ground access, specifically the use of airport rail services in comparison with alternative transportation modes.

A quantitative approach is appropriate because the study seeks to test theoretically derived hypotheses and estimate the relationships between passengers' perceptions, observed travel attributes, and transportation choices. To achieve these objectives, the study employs a Hybrid Choice Model (HCM), which integrates a discrete choice model with a latent variable model. Unlike conventional discrete choice models that primarily rely on observable characteristics and attributes, HCM enables the incorporation of psychological and perceptual factors into the analysis of travel behavior (Ben-Akiva et al., 2002).

The proposed framework consists of three main components. First, seamless transportation represents the primary explanatory construct, reflecting passengers' perceptions of integration across transportation services. Second, perceived convenience and perceived reliability are incorporated as latent psychological constructs that may explain how seamless transportation influences mode choice. Third, the discrete choice component estimates passengers' preferences among available airport ground transportation alternatives while accounting for observed travel attributes, including travel time, travel cost, waiting time, and access distance.

The research model therefore enables the simultaneous examination of the direct relationship between perceived seamless transportation and airport rail choice utility, as well as the indirect relationships operating through perceived convenience and perceived reliability.

Research Setting and Unit of Analysis

The unit of analysis is the individual passenger making a decision about how to travel to or from an airport. The study focuses on passengers who have experience with airport ground



transportation and who are able to evaluate the accessibility, integration, convenience, and reliability of the available transportation alternatives.

The research setting should be specified according to the airport and airport rail service selected for the empirical investigation. The selected setting should provide sufficient variation in transportation alternatives, allowing passengers to compare airport rail with other available modes, such as private vehicles, taxis, ride-hailing services, airport shuttle buses, and other relevant public transportation services.

Eligible respondents should be adults who have undertaken an airport access or egress trip within a clearly defined reference period. Respondents should also be sufficiently familiar with the relevant transportation alternatives to provide meaningful assessments of their service characteristics. These eligibility requirements are intended to ensure that the responses reflect actual travel experiences rather than entirely hypothetical perceptions.

The sampling frame, study location, data collection period, and reference period for respondents' most recent airport trip must be documented explicitly in the final manuscript.

Population and Sampling Technique

The target population comprises airport passengers who make ground transportation decisions when accessing or leaving the airport. Because a complete sampling frame of all eligible airport passengers may not be available, purposive sampling may be employed to recruit respondents who meet the study's eligibility criteria.

The inclusion criteria are as follows: (1) respondents must be at least 18 years old; (2) respondents must have completed an airport access or egress trip during the specified reference period; (3) respondents must have selected a transportation mode for that trip; and (4) respondents must be able to provide information about their travel experience and the relevant transportation alternatives. Where stated-preference scenarios are used, respondents must also be able to evaluate the hypothetical alternatives presented in the questionnaire.

The required sample size should be determined in relation to the complexity of the proposed HCM, the number of estimated parameters, the number and characteristics of the available alternatives, the expected distribution of choices, and the statistical power needed to detect meaningful effects. The number of respondents alone is not sufficient to establish sample adequacy because each respondent may contribute multiple observations when completing stated-preference choice tasks.



A simulation-based sample-size assessment is recommended where feasible, particularly when the model includes several latent constructs and alternative-specific utility parameters. The final manuscript should report the target sample size, the rationale for selecting it, the number of questionnaires collected, and the number of valid observations retained for analysis. The actual sample size should be reported only after data collection.

Data Collection Procedure

Primary data may be collected using a structured questionnaire administered to eligible airport passengers. The questionnaire should be organized into four sections.

The first section collects respondents' demographic and socioeconomic characteristics, including age, gender, employment status, income category, and other relevant personal characteristics. The second section records travel-related information, such as trip purpose, travel frequency, party size, baggage, origin or destination, and the transportation mode used for the most recent airport trip.

The third section measures respondents' perceptions of seamless transportation, perceived convenience, and perceived reliability. These items should be developed from established literature and adapted to the airport ground transportation context. The questionnaire should be reviewed for content validity and pilot-tested to identify ambiguous wording, response difficulties, and problems with the interpretation of the items.

The fourth section presents the transportation choice component. A revealed-preference (RP) component records the transportation mode actually selected for a recent airport trip. A stated-preference (SP) component may additionally present hypothetical choice scenarios in which the attributes of competing transportation alternatives vary systematically. These attributes may include travel time, travel cost, waiting time, access distance, transfer requirements, and the availability of integrated ticketing or travel information.

Combining RP and SP data can provide complementary information: RP observations reflect actual behavior under existing conditions, whereas SP observations allow the analysis of choices under alternative service configurations. If both data sources are used, the estimation procedure should account for differences in their measurement contexts and potential scale differences. The final manuscript must specify whether the analysis uses RP data alone or a combined RP–SP design.



Participation should be voluntary, and respondents should be informed about the research purpose, confidentiality arrangements, and intended use of the data. Any required institutional ethics approval and informed-consent procedures should be completed and reported in accordance with the relevant institutional requirements.

Operationalization and Measurement of Variables

The proposed model includes three latent constructs, one categorical choice outcome, and a set of observed travel attributes and passenger characteristics.

Seamless transportation. Seamless transportation is conceptualized as passengers' perceived degree of integration across different components of an airport ground transportation journey. Its measurement may cover four dimensions: physical integration, temporal integration, information integration, and ticketing integration. Physical integration concerns the ease of moving between transport modes and facilities. Temporal integration concerns coordination between service schedules and connections. Information integration concerns the availability, consistency, and accessibility of travel information. Ticketing integration concerns the ease of purchasing and using tickets across connected services. These dimensions are informed by research emphasizing the importance of integrated multimodal information and reduced passenger effort in public transportation (Grotenhuis et al., 2007).

Perceived convenience. Perceived convenience refers to passengers' overall assessment of the time, effort, and practical ease involved in using a transportation alternative. Relevant indicators may assess ease of access, ease of transferring between services, simplicity of ticket purchasing, and the effort required to plan and complete a journey. The conceptualization draws on the service convenience literature, which emphasizes the time and effort consumers expend when obtaining and using services (Berry et al., 2002).

Perceived reliability. Perceived reliability refers to passengers' assessment of the consistency and predictability of the transportation service. Potential indicators include confidence in the expected travel time, punctuality, consistency of connections, and the perceived likelihood of reaching the airport or final destination within the planned time. This construct is particularly relevant to airport access because uncertainty about arrival time can affect the attractiveness of competing transportation alternatives (Tam et al., 2011).

The latent constructs should be measured using multiple questionnaire items, with responses recorded on a consistent Likert-type scale, such as a five or seven point scale. The exact

items, scale anchors, and sources of adaptation should be reported in the measurement table and questionnaire appendix. Any items developed specifically for this study should be identified as newly developed or contextually adapted rather than presented as verbatim validated scales.

Mode choice. Mode choice is measured as a categorical outcome representing the transportation alternative selected by the passenger. The available alternatives should reflect the actual services in the study setting and may include airport rail, private vehicle, taxi, ride-hailing service, airport shuttle, and other relevant modes. The airport rail alternative can be designated as the reference alternative for model interpretation, provided the choice-set structure supports this specification.

Observed travel attributes and passenger characteristics. The choice model incorporates alternative-specific attributes, including travel time, travel cost, waiting time, and access distance. Additional attributes, such as the number of transfers and the availability of integrated information or ticketing, may be included where they vary across alternatives and can be measured consistently. Passenger characteristics, including income, trip purpose, travel frequency, baggage, and party size, may be incorporated to account for systematic differences in preferences.

A key measurement distinction is that perceived seamless transportation represents a passenger-level latent construct, whereas actual travel time, travel cost, and other alternative-specific characteristics describe the alternatives available to that passenger. The empirical model should preserve this distinction.

Model Specification: Hybrid Choice Model

The study employs an HCM to integrate latent perceptions with a discrete choice framework. The model consists of a measurement model, a structural model for latent variables, and a choice model.

A central feature of HCM is that latent perceptions enter the choice model while being measured imperfectly through observed indicators. Accordingly, the latent variables should not simply be replaced by unadjusted questionnaire scores without considering the resulting measurement error.

A full information HCM estimates the measurement, structural, and choice components jointly or integrates over the distribution of the latent variables when calculating choice probabilities. The joint likelihood combines the information contained in the observed indicators



and the observed transportation choices. Estimation may use maximum simulated likelihood or another estimator appropriate to the selected HCM specification.

This integrated approach enables the analysis to assess whether perceived convenience and perceived reliability help explain differences in transportation choices beyond the effects of observed travel attributes. It also provides a basis for evaluating the proposed mediating mechanisms within the discrete choice framework (Ben-Akiva et al., 2002).

The final manuscript should identify the estimation software, estimator, treatment of ordinal measurement indicators, distributional assumptions for latent variables, normalization restrictions, and procedures used to assess model convergence. These details are necessary to ensure that the HCM can be evaluated and replicated.

Hypothesis Testing and Mediation Analysis

The hypotheses are evaluated using the estimated structural and choice components of the HCM. H1 and H2 are assessed through the coefficients linking seamless transportation to perceived convenience and perceived reliability. Positive and statistically distinguishable coefficients in the hypothesized directions would support these relationships.

H3 and H4 concern the contributions of perceived convenience and perceived reliability to the utility of airport rail relative to the reference alternatives. Their interpretation depends on the utility normalization and the coefficients estimated for the relevant alternatives. H5 evaluates whether seamless transportation contributes directly to relative airport rail utility after accounting for the proposed mediators and observed travel attributes.

H6 and H7 concern the indirect relationships between seamless transportation and airport rail utility through perceived convenience and perceived reliability, respectively. These indirect effects should be evaluated within the integrated model, using an estimator-appropriate procedure such as simulation-based confidence intervals or a parametric bootstrap where supported by the estimation framework. Evidence of a statistically distinguishable indirect effect would support the corresponding mediation hypothesis. The analysis should also distinguish direct, indirect, and total effects where these are identified by the model.

H8 concerns the effects of observed travel attributes on choice utility. The expected direction for travel time, travel cost, waiting time, and access distance is generally negative when these variables are coded as burdens associated with a particular alternative. However, the



interpretation depends on how each attribute is defined, whether it varies across alternatives, and the utility specification used.

Statistical significance should be assessed using a prespecified significance level, conventionally 5%, together with coefficient estimates, standard errors, test statistics, and confidence intervals. Because utility coefficients do not directly represent changes in choice probabilities, predicted probabilities and marginal effects should be reported were substantively useful. These measures provide a more interpretable indication of how changes in seamless transportation or its associated latent perceptions may affect the relative likelihood of choosing airport rail.

Model Evaluation and Robustness Checks

Model evaluation should cover measurement quality, structural relationships, and predictive performance. For the measurement component, the analysis should report appropriate reliability and validity evidence for each latent construct. For the structural component, coefficient estimates, standard errors, confidence intervals, and relevant model diagnostics should be provided.

For the choice component, the study should report the log-likelihood, relevant information criteria where available, and measures of choice prediction appropriate to the selected model. The multinomial logit IIA assumption should be evaluated where applicable. Competing model specifications may be compared to assess whether incorporating latent perceptions improves model fit or explanatory performance relative to a model containing only observed travel attributes.

Robustness checks may include alternative reference alternatives, alternative operationalizations of seamless transportation, and comparisons between RP-only and combined RP–SP models if both data sources are available. Where the data permit, sensitivity analyses can examine whether the estimated relationships differ across passenger groups or trip purposes. Such analyses should be specified and interpreted cautiously to avoid overfitting or making unsupported subgroup claims.

If SP choice tasks are used, the estimation should account for the repeated observations contributed by each respondent. This may require respondent-level clustering, an appropriate panel likelihood, or another estimator consistent with the model structure. The final report should clearly state how repeated choices and any missing observations are handled.



Ethical Considerations

Participation in the study should be voluntary, based on informed consent, and conducted in accordance with applicable institutional ethical requirements. The questionnaire should avoid collecting unnecessary personally identifying information. Research data should be stored securely and used only for the stated research purposes. Any ethics approval, consent procedures, and data availability arrangements should be reported accurately in the final manuscript.

RESULTS AND DISCUSSION

Respondent Characteristics and Descriptive Statistics

The illustrative analysis assumes that 420 valid responses were obtained from airport passengers who had undertaken an airport access or egress trip during the specified reference period. The respondents represented different demographic backgrounds, trip purposes, and transportation preferences. This variation provides a basis for examining the relationships between passengers' perceptions of seamless transportation and their airport ground transportation choices.

The descriptive analysis indicates that airport passengers may evaluate transportation alternatives not only according to travel time and cost but also according to the ease of connecting between services, the availability of integrated travel information, and confidence in arriving at the airport on time. These considerations are particularly relevant when passengers must coordinate ground transportation with airline departure schedules.

The distribution of transportation choices is presented in Table 1.

Table 1. Distribution of airport ground transportation choices

Transportation alternative	Respondents	Percentage
Airport rail	151	36%
Ride-hailing services	105	25%
Private vehicles	76	18%
Taxis	46	1%
Airport shuttle or bus	42	10%
Total	420	100%



In this distribution, airport rail represents the most frequently selected alternative, accounting for approximately 36% of the observations. Ride-hailing services constitute the second-largest category, followed by private vehicles. These figures suggest that airport rail can be a competitive ground transportation alternative, although a substantial proportion of passengers continue to rely on road-based services.

The distribution also illustrates why mode choice should be analyzed as a categorical decision rather than as a conventional continuous dependent variable. Passengers select among competing alternatives, and their decisions reflect the relative attractiveness of the available services. The descriptive results alone, however, cannot establish whether seamless transportation causes passengers to select airport rail. That question requires the structural and discrete choice estimates presented in the following sections.

Measurement Model Assessment

Before estimating the structural relationships, the measurement properties of the latent constructs should be evaluated. In the illustrative analysis, seamless transportation, perceived convenience, and perceived reliability are measured through multiple questionnaire indicators. Table 2 presents hypothetical reliability and convergent validity results.

Table 2. Measurement model assessment

Construct	Number of items	Cronbach's alpha	Composite reliability	AVE
Seamless transportation	12	0.91	0.93	0.64
Perceived convenience	4	0.86	0.90	0.69
Perceived reliability	4	0.88	0.92	0.74

The hypothetical results indicate that Cronbach's alpha and composite reliability exceed the commonly applied threshold of 0.70, suggesting satisfactory internal consistency. The average variance extracted (AVE) values also exceed 0.50, indicating that the constructs account for more than half of the variance in their respective indicators.

These results would provide preliminary evidence that the measurement instruments are sufficiently reliable and exhibit convergent validity. Nevertheless, reliability and AVE alone are insufficient to establish measurement quality. A complete empirical report should also present



indicator loadings, discriminant validity evidence, and any relevant diagnostics for the selected latent variable specification.

In particular, if seamless transportation is modelled as a higher-order construct comprising physical, temporal, informational, and ticketing integration, the researcher must report how those dimensions are operationalized and whether the higher-order construct is reflective or formative. The assessment procedures should be consistent with that specification.

Structural Relationships between Seamless Transportation and Latent Perceptions

The first part of the HCM examines whether passengers' perceptions of seamless transportation are associated with perceived convenience and perceived reliability. Table 3 presents hypothetical estimates for the structural component.

Table 3. Structural model results

Hypothesis	Relationship	Standardized coefficient	p-value	Decision
H1	Seamless transportation → Perceived convenience	0.62	< .001	Supported
H2	Seamless transportation → Perceived reliability	0.54	< .001	Supported

The hypothetical coefficient for H1 is positive and statistically significant ($\beta = 0.62$, ($p < .001$)). This result would indicate that passengers who perceive stronger integration across airport transportation services also tend to report higher levels of convenience. In practical terms, coordinated transfers, accessible travel information, and simplified ticketing may reduce the time and effort passengers need to plan and complete their journeys.

The finding is consistent with the service convenience perspective developed by Berry et al. (2002), which emphasizes the time and effort involved in obtaining and using services. In the airport transportation context, convenience extends beyond the characteristics of an individual transport mode. It also depends on how easily passengers can move between connected services and obtain the information required to make travel decisions.

H2 is also supported in the illustrative results, with a positive coefficient of 0.54 ($p < .001$)). This suggests that greater perceived seamlessness is associated with stronger perceptions



of transportation reliability. Passengers may regard an integrated journey as more dependable when schedules are coordinated, transfer information is clear, and the potential for connection-related uncertainty is reduced.

This interpretation is consistent with research emphasizing the importance of integrated multimodal information in reducing passenger effort and improving the perceived quality of public transportation journeys (Grotenhuis et al., 2007). In airport access, perceived reliability is particularly important because arriving late can have substantial consequences, including missed check-in deadlines or flights.

Taken together, the illustrative structural estimates suggest that seamless transportation may operate through both convenience-related and reliability-related mechanisms. These findings provide the basis for examining whether the two perceptions are subsequently associated with passengers' transportation choices.

Discrete Choice Model Results

The discrete choice component evaluates the relative utility of transportation alternatives by combining latent perceptions with observed travel attributes. The hypothetical specification includes travel time, travel cost, waiting time, access distance, perceived convenience, perceived reliability, and perceived seamless transportation.

For interpretation, the following illustrative estimates represent the utility of airport rail relative to a designated reference alternative. In an empirical HCM, the reference alternative and normalization restrictions must be specified explicitly.

Table 4. Airport rail utility estimates

Explanatory variable	Coefficient	Illustrative standard error	p-value	Expected direction
Perceived convenience	0.41	0.10	< .001	Positive
Perceived reliability	0.35	0.09	< .001	Positive
Seamless transportation	0.18	0.09	.041	Positive
Travel time (minutes)	-0.035	0.008	< .001	Negative
Travel cost (per IDR 10,000)	-0.120	0.035	.001	Negative
Waiting time (minutes)	-0.028	0.009	.002	Negative



Access distance (kilometres)	-0.090	0.030	.003	Negative
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Perceived Convenience and Airport Rail Choice

H3 predicts that perceived convenience positively influences the utility of choosing airport rail. The illustrative estimate is positive and statistically significant ($\beta = 0.41$, $p < .001$), suggesting that passengers who perceive airport rail journeys as convenient may assign greater relative utility to this alternative.

This relationship can be explained by the practical demands of airport travel. Passengers often carry luggage, travel under time constraints, and coordinate their ground journeys with airline schedules. A transportation alternative that minimizes transfer difficulties, simplifies access, and reduces the effort required to obtain travel information may therefore be more attractive.

The result also suggests that improving the passenger experience requires attention to the entire access journey rather than solely to the rail journey itself. For example, a fast rail service may be less attractive if reaching the station requires a difficult transfer or if passengers cannot easily determine the appropriate departure time.

From a managerial perspective, convenience can be strengthened through clearer wayfinding, accessible station connections, simplified ticketing arrangements, and coordinated first-mile and last-mile services. These measures may improve airport rail competitiveness even when substantial reductions in in-vehicle travel time are difficult to achieve.

Perceived Reliability and Airport Rail Choice

H4 examines whether perceived reliability contributes positively to airport rail utility. The illustrative coefficient is positive and statistically significant ($\beta = 0.35$, $p < .001$). This suggests that passengers who perceive airport rail as dependable may be more inclined to select it relative to competing alternatives.

Airport ground transportation decisions differ from many ordinary urban journeys because the consequences of travel-time uncertainty can be substantial. Passengers must allow sufficient time for check-in, baggage handling, security procedures, and boarding. As a result, the predictability of a transportation service may be as important as its average travel time.



This interpretation is consistent with Tam et al. (2011), who examined the relevance of travel-time reliability and perceived service quality to airport ground access mode choice. Their research provides a basis for treating reliability as an important consideration in airport transportation decisions.

The practical implication is that airport rail operators should communicate service information clearly, coordinate feeder services where possible, and minimize uncertainty associated with transfers. Reliability improvements should also be assessed using actual operational performance, including delays and connection failures, rather than relying exclusively on passengers' subjective assessments.

Direct Relationship between Seamless Transportation and Airport Rail Choice

H5 proposes that seamless transportation contributes directly to airport rail utility after perceived convenience, perceived reliability, and observed travel attributes have been considered. The hypothetical estimate is positive and statistically significant ($\beta = 0.18$), ($p = .041$)).

This result would suggest that the perceived integration of transportation services contributes to airport rail attractiveness beyond the contributions associated with convenience and reliability as separately modelled constructs. One possible explanation is that passengers value the coherence of an integrated journey in its own right. Integrated information, coordinated transfers, and consistent ticketing arrangements may make the entire transportation experience easier to understand and manage.

However, the direct coefficient must be interpreted carefully. Its meaning depends on the measurement and structural specification of seamless transportation and the identification of the HCM. Because the latent variables may be correlated, the estimated direct relationship represents the association remaining after accounting for the other included constructs and attributes. It does not establish that seamless transportation has an independent causal effect.

Mediation Analysis

The mediation analysis examines whether perceived convenience and perceived reliability provide indirect pathways connecting seamless transportation with airport rail utility.



Table 5. Indirect effects

Hypothesis	Indirect pathway	Indirect effect	Illustrative 95% confidence interval	Decision
H6	Seamless transportation → Convenience → Rail utility	0.25	[0.14, 0.37]	Supported
H7	Seamless transportation → Reliability → Rail utility	0.19	[0.09, 0.30]	Supported

Mediating Role of Perceived Convenience

H6 proposes that perceived convenience mediates the relationship between seamless transportation and airport rail utility. The illustrative indirect effect is positive (0.25), with a hypothetical 95% confidence interval of [0.14, 0.37]. Because the interval does not include zero, the illustrative result would support the proposed indirect relationship.

The proposed mechanism is that integrated transportation services reduce the effort passengers must expend to complete their journeys, which in turn increases the relative attractiveness of airport rail. Passengers may benefit from easier transfers, more accessible information, and fewer ticketing-related difficulties. These benefits can influence mode choice even when the physical characteristics of the rail service remain unchanged.

This finding would extend the discussion of service convenience by placing it within a multimodal airport transportation framework. Convenience is not simply an attribute of a single service provider; it can emerge from the coordination of several services and facilities that collectively determine the quality of the passenger journey.

The managerial implication is that transport authorities should assess the complete passenger journey, including access to stations, connections with feeder services, ticket purchasing, and information availability. Improvements in these components may help strengthen the competitive position of airport rail.

Mediating Role of Perceived Reliability

H7 proposes that perceived reliability mediates the relationship between seamless transportation and airport rail utility. The illustrative indirect effect is 0.19, with a hypothetical 95% confidence interval of [0.09, 0.30]. This result would support the proposed indirect



relationship if the confidence interval were obtained from an appropriate estimation procedure using actual data.

The proposed mechanism is that better integration can reduce uncertainty associated with connections and travel planning. When passengers have access to consistent information and can anticipate how different services fit together, they may perceive the overall journey as more dependable. This perception may subsequently increase the relative utility of airport rail. The reliability mechanism is particularly relevant to passengers who have limited tolerance for delays because of flight schedules or other travel commitments. For these passengers, the attractiveness of airport rail may depend not only on its scheduled travel time but also on the perceived certainty of completing the journey within the available time window.

Nevertheless, the relative importance of convenience and reliability should not be inferred solely by comparing their indirect-effect estimates unless their scales, model specification, and uncertainty are considered. Formal comparisons or appropriate standardized estimates would be required to establish whether one mechanism is statistically stronger than the other.

Interpreting Direct and Indirect Relationships

If both indirect effects and the direct seamless transportation coefficient are statistically distinguishable from zero in the estimated HCM, the pattern would be consistent with complementary direct and indirect relationships. In conventional mediation terminology, this pattern is sometimes described as partial mediation.

However, the conclusion should reflect the actual integrated model and the identification of its parameters. In particular, the estimated utility coefficients are relative to a reference alternative, and the indirect effects must be calculated using the appropriate structural and choice-model relationships. The presence of statistically significant indirect effects does not, by itself, establish causal mediation in a cross-sectional observational study.

Effects of Observed Travel Attributes

H8 proposes that more favorable travel attributes increase the utility of the relevant transportation alternative. The illustrative results show negative coefficients for travel time, travel cost, waiting time, and access distance.



The negative travel-time coefficient ($\beta = -0.035$, $p < .001$) suggests that longer journeys reduce the relative utility of airport rail, all else being equal. This is consistent with the principle that passengers generally prefer alternatives that allow them to reach the airport within a shorter period, provided other attributes remain constant.

The negative travel-cost coefficient ($\beta = -0.120$, $p = .001$, per IDR 10,000) indicates that higher travel costs reduce utility in the illustrative model. This result highlights the importance of affordability, particularly for passengers who compare airport rail with private vehicles, ride-hailing services, or shared transportation alternatives.

The negative waiting-time coefficient ($\beta = -0.028$, $p = .002$) suggests that longer waits can make an alternative less attractive. Waiting time may be especially consequential when passengers are uncertain about departure schedules or must coordinate the ground journey with a flight.

Finally, the negative access-distance coefficient ($\beta = -0.090$, $p = .003$, per kilometers) indicates that greater distance to the relevant access point can reduce the utility of airport rail. This finding underscores the importance of first-mile connectivity and the accessibility of stations.

These illustrative findings demonstrate why the role of seamless transportation should be examined alongside conventional service attributes. A transportation system may provide integrated information and ticketing, but its competitiveness can remain limited if passengers face excessive access distances, high fares, or long waiting times.

It is also important to distinguish the expected sign of a coefficient from its empirical significance. H8 should be evaluated separately for each attribute or as a clearly defined joint hypothesis. The final manuscript should report the estimates and uncertainty for each coefficient and should avoid concluding that all components of H8 are supported solely because their signs are negative.

Overall Model Performance

The performance of the HCM should be evaluated by comparing the integrated specification with an appropriate baseline model that includes observed travel attributes but excludes latent perceptions.

Table 6 presents a hypothetical model comparison.



Table 6. Comparison of choice model specifications

Model specification	Number of estimated parameters	Log-likelihood	McFadden pseudo-(R ²)
Model 1: Observed travel attributes only	18	-520.4	0.24
Model 2: Observed attributes and latent perceptions	25	-478.6	0.30

In this HCM containing latent perceptions achieves a higher log-likelihood and a higher McFadden pseudo-(R²) than the model based exclusively on observed travel attributes. This pattern would suggest that perceived convenience, perceived reliability, and seamless transportation provide additional explanatory information about passengers' choices.

Nevertheless, an improvement in model fit should not automatically be interpreted as proof of superior predictive performance. The models should be compared using appropriate likelihood-based tests where applicable, information criteria that account for model complexity, or out-of-sample predictive assessment. The selected estimator and the structure of the RP–SP data, if combined, must also be considered.

The HCM's principal contribution is not simply to increase statistical fit. It is to provide a behavioral explanation of how passengers' perceptions interact with objective travel conditions when selecting transportation alternatives. A well-supported integrated model can therefore inform both transportation demand analysis and the design of passenger-oriented airport access services.

Discussion of Theoretical Contributions

The findings presented in this illustrative analysis have three potential theoretical implications. First, they position seamless transportation as a multidimensional feature of the passenger journey rather than merely a characteristic of an individual transportation mode. Integration across physical connections, schedules, information, and ticketing can shape how passengers evaluate the overall journey. This perspective is consistent with research on the value of integrated multimodal travel information and the reduction of passenger time and effort (Grotenhuis et al., 2007).



Second, the proposed mediation mechanisms distinguish two potentially complementary processes through which integration may influence transportation preferences. Perceived convenience captures the effort and practical ease associated with completing the journey, whereas perceived reliability captures confidence in its predictability. These constructs may be related, but they should not be treated as interchangeable. The distinction allows researchers to examine whether passengers value seamless transportation because it makes a journey easier, because it makes the journey more dependable, or because it contributes to both perceptions.

Third, the use of an HCM offers a methodological contribution by integrating latent perceptions with the utility-based representation of transportation choices. Conventional discrete choice analysis provides a rigorous framework for modelling choices among alternatives based on their attributes (Ben-Akiva & Lerman, 1985; Train, 2009). However, passengers may also respond to perceptions that cannot be directly observed through travel time or fare data. The HCM framework developed by Ben-Akiva et al. (2002) provides a basis for incorporating these latent factors into choice analysis.

These contributions should ultimately be framed in relation to the estimated evidence and the existing literature. The illustrative results demonstrate how the theoretical arguments can be connected to an empirical analysis, but they cannot establish that the proposed relationships have been confirmed in the actual research setting.

Managerial and Policy Implications

The proposed findings suggest several implications for airport operators, rail service providers, transport authorities, and other stakeholders responsible for airport accessibility. First, improve integration across the complete passenger journey. Airport rail competitiveness depends not only on rail operations but also on the ease with which passengers reach stations, transfer between modes, and obtain consistent travel information. Transport authorities should identify barriers at the interfaces between services and prioritize improvements that reduce passenger effort.

Second, strengthen travel information and ticketing integration. Clear and consistent information regarding schedules, connections, fares, and disruptions can help passengers plan their journeys with greater confidence. Where operationally and institutionally feasible, integrated ticketing and coordinated passenger information can reduce transaction costs and simplify multimodal travel.



Third, prioritize reliability as a core service objective. Airport passengers often operate under fixed time constraints. Rail operators and feeder-service providers should therefore coordinate schedules where possible, communicate disruptions promptly, and monitor service punctuality and connection performance. Reliability initiatives should be evaluated using both operational data and passenger perceptions.

Fourth, improve first-mile and last-mile connectivity. A station may provide a reliable rail service but remain unattractive if it is difficult to reach. Accessible pedestrian routes, feeder buses, suitable drop-off arrangements, and effective connections with other transportation services may reduce access barriers.

Fifth, balance integration improvements with time and cost competitiveness. Seamless transportation should not be treated as a substitute for competitive fares and reasonable travel times. An integrated service may still be unattractive when its total journey time or cost substantially exceeds those of competing alternatives. Planning decisions should therefore consider integration, convenience, reliability, travel time, and cost jointly.

Finally, decision-makers should avoid assuming that all passengers respond to these attributes in the same way. Business travelers, leisure travelers, frequent flyers, passengers traveling in groups, and passengers carrying substantial luggage may have different priorities. Such differences can be investigated through appropriately designed subgroup or heterogeneity analyses, provided the available data support those analyses.

Summary of Hypothesis Testing

Summarizes the hypothetical hypothesis-testing results.

Table 7. Summary of hypotheses

Hypothesis	Proposed relationship	Illustrative conclusion
H1	Seamless transportation → Perceived convenience	Supported
H2	Seamless transportation → Perceived reliability	Supported
H3	Perceived convenience → Airport rail utility	Supported
H4	Perceived reliability → Airport rail utility	Supported
H5	Seamless transportation → Airport rail utility	Supported
H6	Mediation through perceived convenience	Supported
H7	Mediation through perceived reliability	Supported



H8	More favourable observed travel attributes increase relevant alternative utility	Requires attribute-specific assessment
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Overall, the analysis demonstrates how an HCM can be used to investigate the relationships among seamless transportation, passenger perceptions, observed travel attributes, and airport ground transportation choices. The framework emphasizes that the competitiveness of airport rail may depend not only on conventional service characteristics but also on how passengers experience the integration and coordination of their journeys. Actual conclusions about the proposed relationships, their relative importance, and their implications for airport transportation policy must be established through the analysis of observed research data.

CONCLUSION, IMPLICATIONS, AND FUTURE RESEARCH

Conclusion

This study develops an integrated framework for examining the relationship between seamless transportation and airport passenger mode choice, with particular attention to the mediating roles of perceived convenience and perceived reliability. By incorporating latent psychological constructs into a discrete choice framework, the proposed Hybrid Choice Model (HCM) provides a means of examining how passengers evaluate transportation alternatives beyond conventional attributes such as travel time, travel cost, waiting time, and access distance.

The results presented in this study suggest that seamless transportation may contribute to airport rail attractiveness through several complementary mechanisms. First, greater perceived integration across transportation services may enhance perceived convenience by reducing the time and effort required to plan and complete a journey. Second, seamless transportation may strengthen perceived reliability by improving passengers' confidence in service coordination, travel information, and transfer arrangements. These relationships highlight the importance of evaluating airport transportation as an integrated passenger journey rather than as a collection of independent transport services.

The proposed framework further suggests that perceived convenience and perceived reliability may contribute to the relative utility of airport rail. Convenience reflects the practical ease of using the service, whereas reliability reflects the predictability of the journey. Both dimensions are particularly relevant to airport access because passengers must coordinate ground transportation with fixed flight schedules and other travel requirements. Previous



research on airport ground access has similarly emphasized the relevance of travel-time reliability and perceived service quality in understanding passengers' transportation choices (Tam et al., 2011).

In addition, conventional travel attributes remain important components of airport mode choice. Travel time, travel cost, waiting time, and access distance can influence the relative attractiveness of transportation alternatives, even when integration and passenger perceptions are considered. Consequently, seamless transportation should be understood as a complement to competitive operational performance rather than a substitute for it.

The methodological contribution of the study lies in the proposed integration of latent perceptions and discrete transportation choices. HCM provides a framework for incorporating psychological factors into utility-based choice models, thereby extending the analysis beyond specifications based exclusively on observable travel characteristics (Ben-Akiva et al., 2002). This approach can help researchers and transportation planners investigate not only which attributes are associated with mode choice but also the perceptual mechanisms through which service integration may influence passenger preferences.

However, the findings discussed in this manuscript remain illustrative until they are verified using actual empirical data. The substantive conclusions concerning hypothesis support, the magnitude of direct and indirect effects, and the predictive performance of the model must therefore be established through the estimation of the proposed HCM using observed passenger choices.

Theoretical Implications

This study offers three potential theoretical contributions to the literature on transportation behavior and airport accessibility. First, it conceptualizes seamless transportation as a multidimensional feature of the passenger journey. Physical connectivity, temporal coordination, information integration, and ticketing integration may jointly shape passengers' evaluations of multimodal transportation. This perspective extends the focus beyond the characteristics of individual transport operators and emphasizes the importance of coordination across the overall journey. The importance of integrated multimodal information and reduced passenger effort is consistent with the arguments developed by Grotenhuis et al. (2007).

Second, the study distinguishes perceived convenience from perceived reliability as two potential mechanisms linking seamless transportation with mode choice. Although the constructs



may be related, they represent different aspects of passenger evaluation. Convenience concerns the effort and practical ease required to complete a journey, whereas reliability concerns the predictability and consistency of the service. Incorporating both constructs enables a more differentiated examination of how passengers respond to integrated transportation services. This distinction is relevant to the service convenience literature and to research examining reliability in airport ground access decisions (Berry et al., 2002; Tam et al., 2011).

Third, the study advances a behavioral modelling perspective by integrating latent perceptions with discrete choice analysis. Traditional choice models provide a systematic means of estimating preferences among competing transportation alternatives, while HCM allows psychological constructs to be incorporated into the utility specification and measurement process (Ben-Akiva et al., 2002; Train, 2009). This integration may provide a richer representation of airport passenger decision-making, particularly when perceptions of convenience, reliability, and service integration are not directly observable.

These contributions should be interpreted as theoretical propositions until the model has been estimated and evaluated using actual data. The extent to which the proposed framework advances existing empirical knowledge will depend on its measurement quality, parameter identification, model fit, and ability to explain observed transportation choices.

Managerial and Policy Implications

The proposed framework has several implications for airport authorities, airport rail operators, public transportation providers, and policymakers responsible for multimodal connectivity.

Develop an Integrated Passenger Journey

Airport accessibility should be planned from the perspective of the complete passenger journey rather than the performance of individual transportation modes. An airport rail service may offer competitive travel times but remain unattractive if passengers experience difficult station access, poorly coordinated transfers, or fragmented travel information.

Airport authorities and transport operators should therefore identify barriers at the interfaces between transport services. Improving pedestrian connections, coordinating feeder services, simplifying transfers, and providing consistent wayfinding can help reduce the effort



required to reach the airport. These measures should be evaluated across the entire journey, including the first-mile and last-mile segments.

Improve Reliability and Information Coordination

Because airport passengers operate under time constraints, the predictability of ground transportation is an important consideration. Transport providers should prioritize operational reliability, communicate service disruptions promptly, and coordinate connections where feasible.

Integrated passenger information should communicate departure times, expected travel durations, transfer requirements, fare information, and alternative routes during disruptions. Such initiatives may help passengers make informed decisions and reduce uncertainty about the journey. These recommendations are consistent with the importance of reliability and perceived service quality in airport ground access mode choice identified by Tam et al. (2011).

Strengthen Ticketing and Payment Integration

Fragmented ticketing arrangements may increase the time and effort needed to complete a multimodal journey. Where institutional and technical conditions permit, transport authorities should consider integrated ticketing, interoperable payment systems, and clearer fare information.

The objective is not necessarily to establish a single ticketing platform in every setting, but to reduce unnecessary transaction costs and make connections between transportation services easier to understand and use. Ticketing improvements should be assessed alongside physical connectivity and service coordination because integration is unlikely to be effective when other major barriers remain unresolved.

Balance Integration with Time and Cost Competitiveness

Integration initiatives should complement improvements in travel time, fare affordability, waiting time, and station accessibility. A seamless service may still be unattractive if its total journey time is excessive or its cost substantially exceeds competing alternatives.

Airport rail planning should therefore combine operational performance indicators with passenger-oriented measures. Relevant indicators include door-to-door travel time, transfer time, total journey cost, service punctuality, access distance, passenger satisfaction, and the ease



of obtaining travel information. The relative importance of these indicators should be established through empirical analysis rather than assumed to be identical across passenger groups.

Use Behavioral Models to Support Transport Planning

The HCM framework may help decision-makers evaluate proposed service improvements by estimating how changes in travel attributes and passenger perceptions relate to transportation choices. For example, a planning scenario could examine the potential consequences of reducing waiting time, improving feeder connections, or introducing more integrated passenger information.

However, scenario-based predictions should only be produced after the model has been estimated, validated, and calibrated using appropriate data. The illustrative coefficients in this manuscript must not be used to forecast actual mode shares or to justify investment decisions.

Limitations and Future Research

Several limitations provide opportunities for further investigation. First, if the empirical study uses a cross-sectional survey, the estimated relationships will primarily represent associations observed at a particular point in time. Although the proposed framework specifies direct and indirect pathways, cross-sectional data alone cannot establish temporal ordering or definitive causal effects. Future research could use longitudinal data to examine whether improvements in transportation integration are followed by changes in passenger perceptions and actual mode choices.

Second, the proposed model focuses on perceived convenience and perceived reliability as mediating constructs. Other psychological and behavioral factors may also influence airport transportation decisions. Future studies could examine perceived safety, comfort, environmental awareness, habit, trust in service providers, perceived value, or attitudes toward public transportation. Additional constructs should be incorporated only when supported by a clear theoretical rationale and an identifiable empirical contribution.

Third, the measurement of seamless transportation requires further development and validation. Physical, temporal, informational, and ticketing integration may represent distinct dimensions whose relative importance varies across transportation systems. Future research could compare alternative measurement specifications, including multidimensional latent constructs and formative composite models. Cross-context validation would also help establish



whether the measurement instrument is applicable across different airports and institutional settings.

Fourth, airport passenger preferences may be heterogeneous. Business and leisure travelers, frequent and occasional flyers, passengers traveling alone or in groups, and passengers carrying different amounts of baggage may assign different importance to travel time, reliability, convenience, and cost. Future research could investigate this heterogeneity through mixed logit models, latent class models, or appropriately specified interactions, provided that the data and sample size support the additional parameters.

Fifth, the empirical scope of the study may limit generalizability. Passenger behavior can differ according to airport size, the availability of direct rail services, the quality of road access, the structure of local public transportation, and the characteristics of the surrounding urban area. Comparative research across airports and regions could determine whether the proposed relationships remain consistent under different service and institutional conditions.

Sixth, if stated-preference scenarios are used, hypothetical choices may differ from actual behavior because respondents do not face the same financial and time constraints when answering a questionnaire. Combining revealed-preference and stated-preference data may help address this limitation, although differences in scale and behavioral context must be modelled appropriately. Future studies could also compare stated preferences with subsequent observed travel behavior to evaluate the predictive validity of the estimated model.

Finally, future research should evaluate not only explanatory performance but also predictive accuracy and policy relevance. Model comparisons, out-of-sample validation, sensitivity analysis, and scenario testing can help determine whether incorporating latent perceptions improves the practical usefulness of transportation choice models. Where feasible, researchers could link survey responses with operational data on punctuality, waiting time, service disruptions, and actual travel durations to strengthen the connection between passenger perceptions and observed service performance.

Final Conclusion

Seamless transportation provides a useful perspective for understanding airport ground transportation as an integrated journey shaped by both observable service attributes and passenger perceptions. By considering perceived convenience and perceived reliability within a Hybrid Choice Model, this study proposes a framework for investigating how multimodal



integration may contribute to airport rail attractiveness relative to competing transportation alternatives.

The framework highlights the potential value of coordinating physical connections, service schedules, travel information, and ticketing while maintaining competitive travel times, reasonable costs, and dependable operations. It also offers a basis for examining how passengers evaluate the overall quality of an airport access journey.

Ultimately, the empirical contribution of the study will depend on the validation of its measurement instruments, the appropriate estimation of the integrated choice model, and the robustness of its findings using actual passenger data. With these conditions satisfied, the framework may contribute to a more behaviorally informed understanding of airport accessibility and support evidence-based strategies for improving multimodal transportation integration.

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