

ESTIMATING DOMESTIC AVIATION DEMAND USING THE FOUR-STEP TRAVEL DEMAND MODEL: A DISAGGREGATE APPROACH

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ABSTRACT

Conventional aviation demand forecasting relies on the city-pair model, requiring historical Origin-Destination (O-D) traffic data and a mature network — conditions absent in developing economies and geographically compact island states such as Sri Lanka. Through a critical literature review, this study proposes an adaptation of the Four-Step Travel Demand Model as a city-pair demand estimation framework applicable to both existing aerodrome locations. A preliminary passenger profiling stage identifies traveller segments for whom air travel is feasible. Trip generation then estimates long-distance trip volumes as a function of household income, employment structure, population density, and tourism activity. Trip distribution constructs an O-D matrix using a gravity formulation with economic mass and tourism potential as attractiveness measures and generalised cost as impedance. Mode choice applies a disaggregate choice model within the Random Utility Maximisation framework, with utility specified across travel time, access time, service frequency, comfort, and cost. Route assignment is omitted as inapplicable at the city-pair level. Empirical validation through stated preference surveys, targeting aviation-feasible traveller segments across origin catchment areas, constitutes the essential next step.

Keywords: aviation demand modelling, four-step model, discrete choice model, origin-destination matrix

1. INTRODUCTION

The planning and development of aviation infrastructure requires reliable passenger demand estimates to support investment decisions, route development, and policy formulation. In established aviation markets, demand forecasting is conventionally achieved through the city-pair model, which analyses historical Origin-Destination (O-D) traffic flows between specific airport pairs to project future passenger volumes, relying on established service records and market maturity as its foundational inputs (Jorge-Calderón, 1997). However, in regions characterised by limited or non-existent scheduled air services, the absence of historical traffic data renders this methodology fundamentally inapplicable, creating a critical planning gap that is particularly acute for domestic aviation in developing economies.

Without credible demand estimates, infrastructure planning and investment decisions are made under significant uncertainty, increasing the risk of resource misallocation. Addressing this gap requires alternative frameworks capable of generating demand estimates from socioeconomic and mode choice behavioural data rather than historical traffic records of air travel. This study proposes adapting the Four-Step Travel Demand Model, a well-established methodology in land transport planning, as a viable framework for estimating domestic aviation demand between city pairs, supported by a critical review of the relevant literature that establishes the theoretical basis and justifies the proposed approach.

2. LITERATURE REVIEW

The literature on aviation demand modelling broadly distinguishes between aggregate econometric models and disaggregate behavioural models. Aggregate approaches relate total passenger volumes to macroeconomic variables such as Gross Domestic Product, trade flows,

and population using regression or gravity formulations (Jorge-Calderón, 1997). Whilst computationally straightforward, these models cannot capture the behavioural heterogeneity of individual travellers, limiting their utility for local-level demand estimation. The city-pair model, the most widely applied route-level framework, estimates demand between specific airport pairs using historical O-D data, fare levels, and service frequency, relying on established traffic records and market maturity as its foundational inputs (Jorge-Calderón, 1997). Its structural dependence on such records renders it incompatible with new aviation markets where historical data are absent.

The Four-Step Travel Demand Model (4STM) emerged as the dominant framework for regional transport demand estimation during the late 1950s and 1960s, formalised through landmark studies such as the Chicago Area Transportation Study, and operates through trip generation, trip distribution, mode choice, and route assignment, each informed by socioeconomic, land use, and network characteristics (McNally, 2008). (Ortúzar & Willumsen, 2011) demonstrate that the 4STM is applicable beyond urban contexts, extending to intercity and long-distance travel demand estimation, establishing a clear precedent for its transferability to aviation demand. The disaggregate variant, grounded in random utility theory, operates at the level of individual decision-makers and produces behaviourally realistic demand estimates through discrete choice models such as the Multinomial Logit and Nested Logit, which express mode utility as a function of travel time, access time, service frequency, cost, and comfort — attributes directly applicable to the aviation mode choice context (Ben-Akiva & Lerman, 1991). The role of tourism as a driver of long-distance travel demand has received relatively limited attention within the conventional 4STM literature. Yet, in regional aviation contexts, leisure travel frequently constitutes a substantial share of potential demand, necessitating the explicit incorporation of tourism variables into the modelling framework.

The critical review confirms a clear methodological gap: neither aggregate econometric models nor city-pair formulations can estimate aviation demand between city pairs in data-scarce environments, as both assume market maturity that does not exist in nascent aviation markets. The 4STM, adapted to the aviation context and applied at the disaggregate level, presents a theoretically sound and practically viable alternative.

3. METHOD

This study employs a critical literature review. Sources were selected for their relevance to aviation demand modelling, land transport demand estimation, discrete choice theory, and catchment area analysis, and were critically appraised and synthesised to identify the research gap and establish the theoretical justification for the proposed framework.

The proposed framework targets city-pair domestic aviation demand and is applicable to both existing and potential aerodrome locations, including greenfield sites where no service currently exists. A preliminary passenger profiling stage identifies the traveller segments for whom air travel constitutes a feasible mode, based on trip purpose, income class, and journey distance. Trip generation then estimates the volume of long-distance trips generated from each origin catchment zone as a function of household income, employment structure, population density, and tourism activity. Trip distribution constructs an O-D matrix between origin zones and destinations using a gravity model, with destination attractiveness defined by economic mass and tourism potential, and impedance expressed as a function of travel time and generalised cost. Mode choice applies a disaggregate discrete choice model, structured within the Random Utility Maximisation framework, to allocate long-distance trips between air and surface modes; utility is specified as a function of travel time, access time, service frequency, comfort, and cost. The route assignment step is omitted as it does not apply to city-pair demand estimation. Primary data for model calibration will be collected through stated preference surveys targeting aviation-

feasible traveller segments, supplemented by secondary data from census records, tourism statistics, and transport schedules.

4. RESULTS AND DISCUSSION

The critical review establishes that both dominant aviation demand modelling approaches — aggregate econometric models and the city-pair model — are unsuitable for estimating city-pair demand in data-scarce, nascent aviation environments. Aggregate models lack the resolution required for city-pair analysis, whilst the city-pair model assumes historical traffic data and market maturity that do not exist in developing economy contexts (Jorge-Calderón, 1997). This confirms that an alternative methodological approach is both necessary and academically justified, and that any viable framework must be capable of generating demand estimates from socioeconomic and behavioural inputs rather than from historical service records.

The review confirms that the disaggregate 4STM provides a sound basis for demand estimation in such environments. The precedent established by (Ortúzar & Willumsen, 2011) for long-distance 4STM application, combined with the random utility framework of (Ben-Akiva & Lerman, 1991), supports its transferability to city-pair aviation demand estimation. The O-D matrix framework systematically quantifies long-distance trip volumes and directionality between origin zones and city-pair destinations applicable to existing aerodromes and greenfield locations alike, a capability absent from aggregate approaches. The preliminary profiling stage further strengthens the framework by bounding the modelled demand population to aviation-feasible traveller segments, improving behavioural realism. The incorporation of tourism variables into trip generation and distribution additionally addresses a recognised gap in the conventional application of the 4STM to long-distance travel in regional aviation contexts.

5. CONCLUSION

This paper demonstrates, through a critical review of the relevant literature, that conventional aviation demand modelling approaches are fundamentally inapplicable in data-scarce environments where historical traffic records and mature air services are absent. The proposed adaptation of the Four-Step Travel Demand Model, comprising a passenger profiling stage followed by trip generation, trip distribution, and disaggregate mode choice, provides a theoretically robust framework for estimating city-pair domestic aviation demand in developing economies and geographically compact island contexts, applicable to both existing and potential aerodrome locations. The integration of tourism variables further extends the framework's relevance where leisure travel constitutes a principal demand driver.

The principal contribution is a transferable methodological framework enabling planners and policymakers to generate credible city-pair demand estimates in markets that cannot be served by conventional forecasting tools. Future work should focus on empirical calibration through stated preference surveys designed to elicit aviation-feasible traveller segment profiles and mode utility parameters across origin catchment areas, followed by validation against observed outcomes in comparable nascent aviation markets. Further research may examine the sensitivity of the mode choice component to variations in fare, frequency, and access time to improve the precision of modal share estimates across city pairs.

6. REFERENCES

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