

Regional Air Mobility Flight Demand Modeling in Tennessee State

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- Urbanization has accelerated rapidly with various global challenges
 - Heightened pollution
 - Traffic delay
 - More accidents
 - Higher vehicle operation cost
- Medium-distance trips (50–500 miles) face congestion, limited airport access, and underserved routes, leading to inconvenient alternatives.
- Advanced Air Mobility (AAM) offers efficient, eco-friendly transport using electric and autonomous aircraft.

- AAM is divided into:
 - Regional Air Mobility (RAM) which operated at regional level
 - Urban Air Mobility (UAM) which operates at city level
- RAM has various implementation challenges, our focus is on demand modeling
- We focus on Tennessee State:
 - In Metropolitan Statistical Areas (MSAs) level (one or more counties with population of 50,000 or more)
 - Considering five major airports as the RAM port initially and then including nearest airports for each MSAs.

Table: Metropolitan Statistical Areas in Tennessee State

Metropolitan Statistical Areas	CBSA code
Chattanooga, TN-GA	16860
Clarksville, TN-KY	17300
Cleveland, TN	17420
Jackson, TN	27180
Johnson City, TN	27740
Kingsport-Bristol-Bristol, TN-VA	28700
Knoxville, TN	28940
Memphis, TN-MS-AR	32820
Morristown, TN	34100
Nashville-Davidson-Murfreesboro-Franklin, TN	34980

Table: Major Airports in Tennessee under consideration for RAM station

Airports	IATA Code	Location(MSA)
Nashville International Airport	BNA	Nashville(34980)
Memphis International Airport	MEM	Memphis(32820)
McGhee Tyson Airport	TYS	Alcoa(28940)
Lovell Field Airport	CHA	Chattanooga(16860)
Tri-Cities Airport	TRI	Blountville(28700)

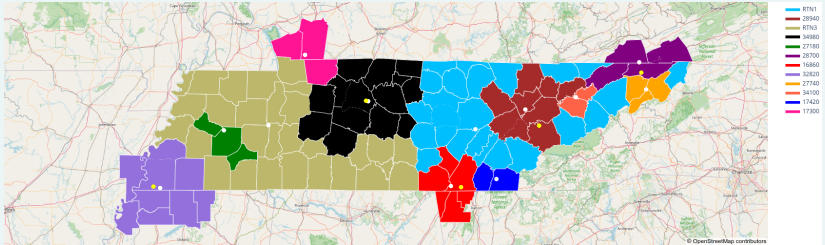


Figure: Overview of the Tennessee Region

- Four-step travel demand model:
 - Trip generation
 - Trip distribution
 - Mode choice (focus of this study)
 - Route choice



Figure: Four Step Model for travel demand modeling

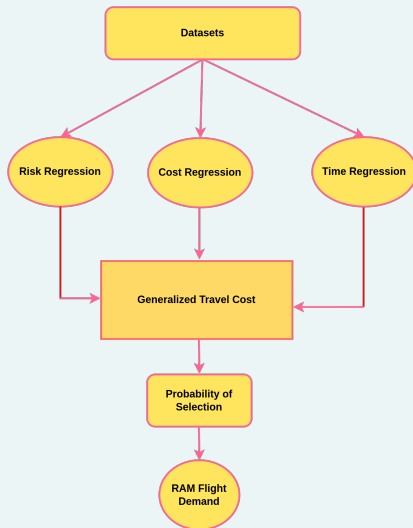


Figure: Methodology

Name	Details
BTS Monthly Traffic Dataset	Number of fatalities during Transportation
USDA VSL Dataset	Monetary equivalent of reducing one death in population
NHTS Dataset	Trip Demand in MSA level
Gazetteer Files	Centroid of population of MSA
BTS DB1BMarket Dataset	Ticket Price for the airlines
IRS Standard Mileage Dataset	Standard Mileage Rates(cents/miles)
FAA Airport Dataset	Block time of the flights
BTS Inter-Airport Distance Dataset	Distance between the airports
Google Map API	Distance and Time of Ground transportation
US Bureau of Labor Statistics	Median hourly wages

Figure: Dataset used in the research

Assumption for the trips:

- Generated from the centroid of population of MSAs.
- Ground transportation trip consists of distance travel between centroids
- RAM trip consists of:
 - Ground transportation from centroid of origin MSA to the nearest hub airport
 - RAM flight to destination airports
 - Finally ground transportation from destination airports to the centroid of destination MSA.

Feature	All Trips	Trips (50-500 miles)
Trip Distance Distribution	0-10 miles: 72.67%	
	10-25 miles: 20.04%	
	25-50 miles: 5.46%	50-75 miles: 46.31%
	50-75 miles: 0.85%	75-100 miles: 20.71%
	75-100 miles: 0.38%	100-150 miles: 17.51%
	100-150 miles: 0.32%	150-300 miles: 13.68%
	150-300 miles: 0.25%	>300 miles: 1.79%
	>300 miles: 0.03%	
Preferred Mode of Transportation	Vehicle: 92.609%	Vehicle: 99.892%
	Active Transportation/Ferries: 7.380%	Airways: 0.095%
	Rail: 0.009%	Rail: 0.013%
	Airways: 0.002%	Active Transportation/Ferries: 0.0%
Purpose of Trip	Work: 25.81%	Work: 29.46%
	Non_Work: 74.19%	Non_Work: 70.54%
Monthly Trip Demand	Highest: August Lowest: February	Highest: October, followed by August Lowest: February
Trip Demand by MSA	Highest: 34980 (29.45%) Lowest: 34100 (1.78%)	Highest: 34980 (30.41%) Lowest: 17420 (1.30%)
Most Popular OD Pair	Highest: RTN1 to 28940 (8.59%) Lowest: 27180 to 27740 (0.0006%)	Highest: RTN3 to 34980 (8.35%) Lowest: 27180 to 27740 (0.002%)

Figure: Comparison of trips

Ground Transportation

$$C_G = d * \beta \quad (1)$$

where

- C_G is cost of trip per mile per passenger for ground transportation
- d is driving distance derived from the Google Map Distance Matrix API Service
- β is standard mileage rates provided by the United States Internal Revenue Services

Air Transportation

- Airfare is influenced by travel distance, service class, booking timing, competition, and airline concentration.
- Passenger costs are directly linked to distance for modeling purposes.
- Utilizes the DOT's DB1B database (2021–2022), covering a 10% sample of U.S. ticket sales.

- Ground Transportation
 - Google Map Distance Matrix API service
- Airlines
 - Block time from Aviation System Performance Metrics (ASPM) dataset
 - BTS inter-airport distance dataset

$$\begin{aligned}R_G &= VSL * \alpha_G \\ R_A &= VSL * \alpha_A\end{aligned}\tag{2}$$

where

- R_m is Risk of trip for m mode of transportation
- VSL is Value of Statistical Life
- α_m is fatality rate during m mode of transportation

$$\begin{aligned}
 GTC_G &= -C_G - W * T_G - R_G \\
 GTC_A &= -C_A - W * T_A - R_A
 \end{aligned}
 \tag{3}$$

where:

- GTC_m is Generalized travel cost for m mode of transportation
- C_m is Cost of trip per mile per passenger for m mode of transportation
- W Average median hourly wage of origin and destination MSA
- T_m is Time of trip for m mode of transportation
- R_m is Risk of trip for m mode of transportation

$$GTC_{RAM} = GTC_G + GTC_A \tag{4}$$

$$\begin{aligned}U_G &= GTC_G + \epsilon \\U_{RAM} &= GTC_{RAM} + \epsilon\end{aligned}\tag{5}$$

where:

- U_m Utility for m mode of transportation
- GTC_m GTC for m mode of transportation
- ϵ is the error introduced

$$P_{\text{RAM}} = \frac{1}{1 + e^{(U_G - U_{\text{RAM}})}} \quad (6)$$
$$P_{\text{RAM}} = \frac{1}{1 + e^{(GTC_G - GTC_{\text{RAM}})}}$$

where:

- P_{RAM} Probability of selecting RAM transportation

Air Transportation

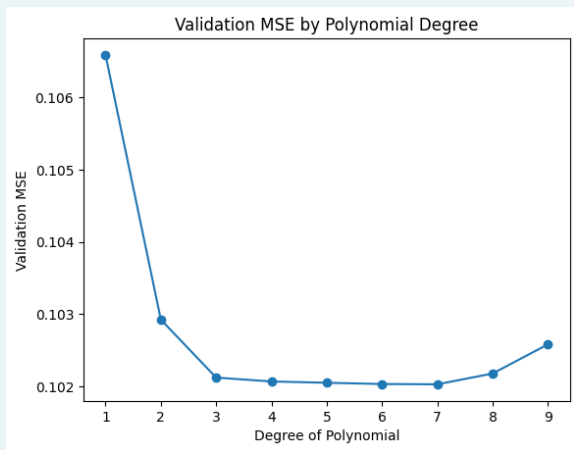


Figure: MSE with various degrees of Polynomial

Air Transportation

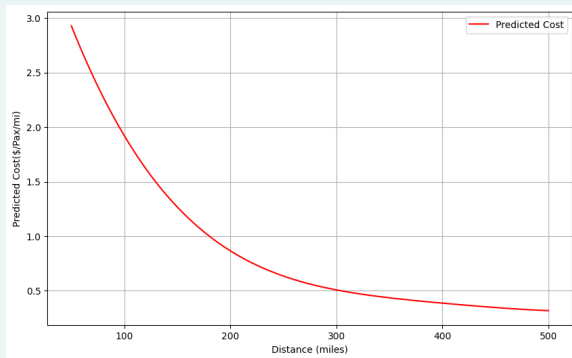


Figure: Cost Regression

Ground Transportation

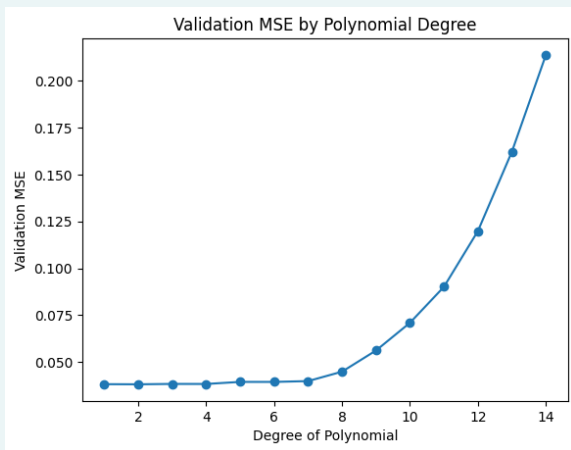


Figure: MSE with various degrees of Polynomial

Ground Transportation

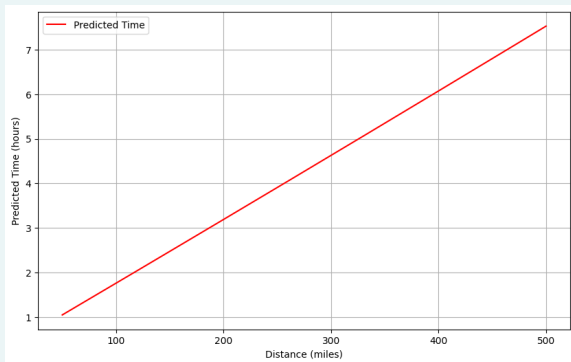


Figure: Time Regression Analysis

Air Transportation

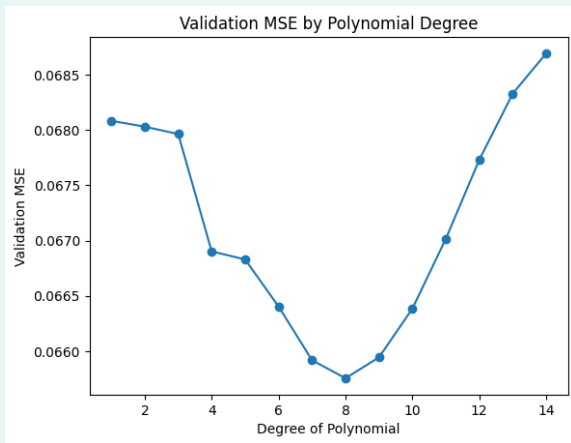


Figure: MSE with various degrees of Polynomial

Air Transportation

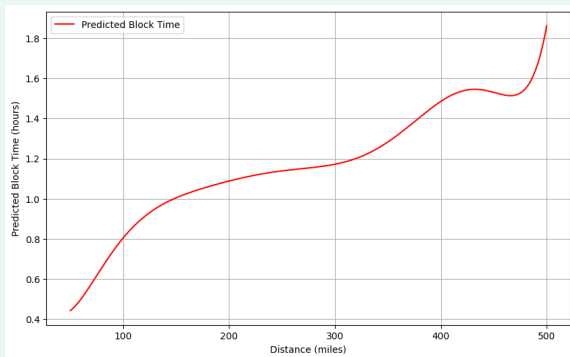


Figure: Block Time Regression Analysis For Airlines

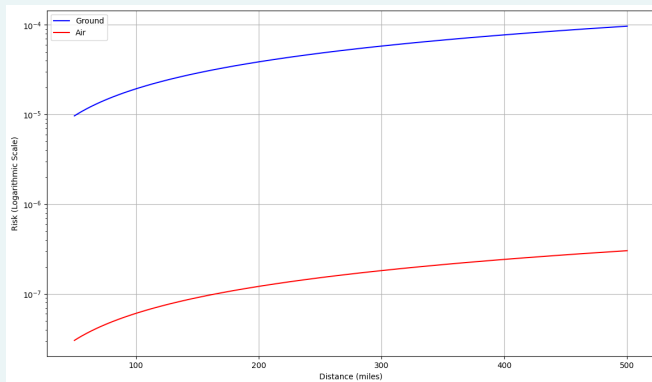


Figure: Risk regression for different modes of Transportation

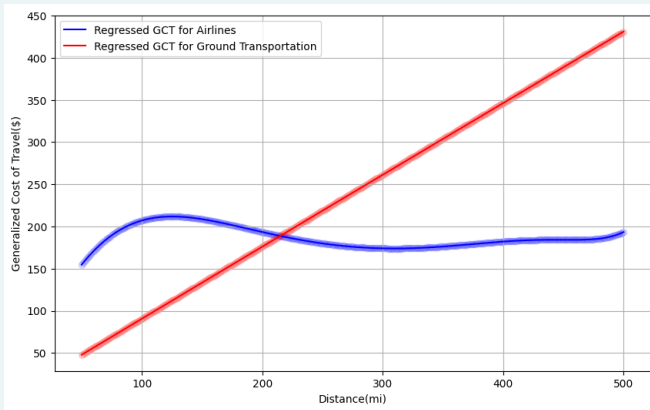


Figure: Regression Analysis For Generalized Travel Cost

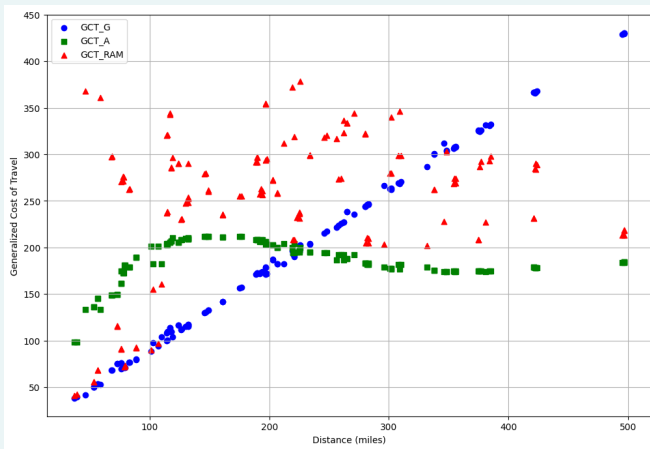


Figure: Generalized Travel Cost for various modes for different OD pairs for Case I

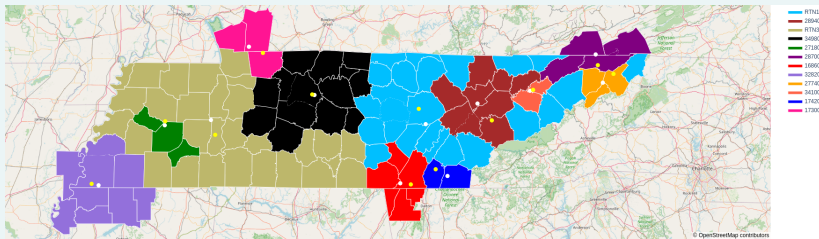


Figure: MSAs with corresponding nearest airports in Tennessee State Region

Table: Nearest Airports from MSA

Airports	IATA Code	MSA (City)
Nashville International Airport	BNA	34980 (Nashville)
Memphis International Airport	MEM	32820 (Memphis)
McGhee Tyson Airport	TYS	28940 (Alcoa)
Lovell Field Airport	CHA	16860 (Chattanooga)
Tri-Cities Airport	TRI	28700 (Blountville)
Elizabethton Municipal	0A9	27740 (Elizabethton)
Scott	0M1	RTN3 (Parsons)
Outlaw	CKV	17300 (Clarksville)
Crossville Memorial	CSV	RTN1 (Crossville)
Hardwick	HDI	17420 (Cleveland)
Humboldt Municipal	M53	27180 (Humboldt)
Moore-Murrell	MOR	34100 (Morristown)

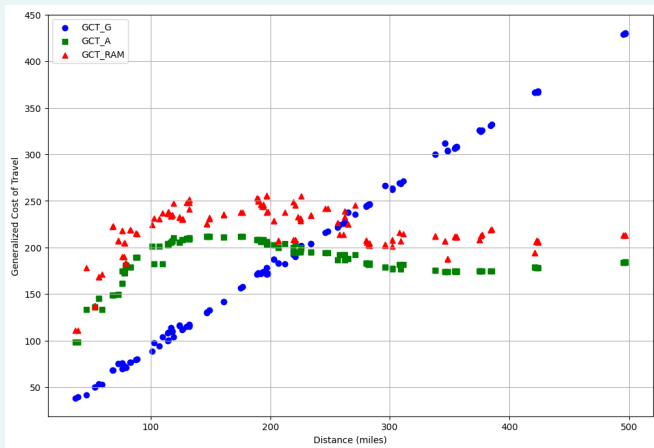


Figure: GTC for various modes for different OD pairs for Case II

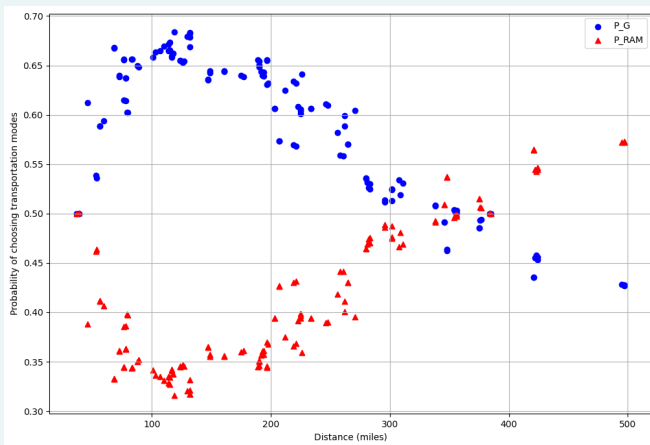


Figure: Probability of selecting transportation mode

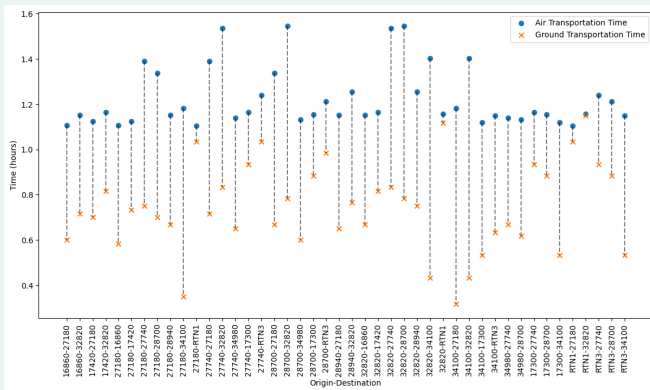


Figure: Air and Ground Transportation Time for RAM Trip

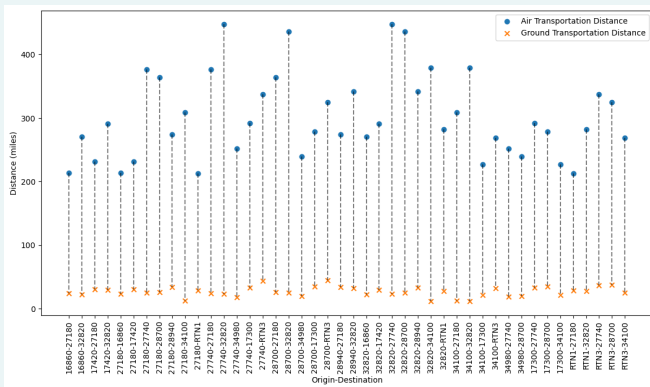


Figure: Air and Ground Transportation Distance for RAM Trip

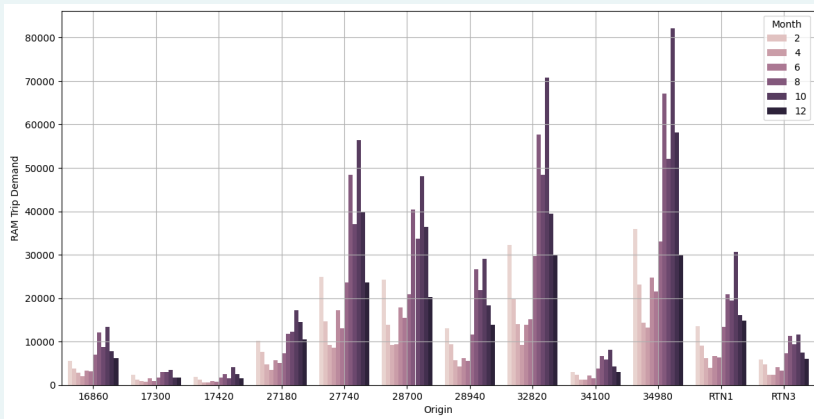


Figure: Monthly RAM Trip Demand for Each Origin

- Demonstrates RAM as a viable alternative for trips exceeding 300 miles or when air travel dominates over 80% of the GTC.
- OD pairs with $GTC > 300$ and air travel time > 1 hour show high potential for RAM adoption.
- Highlights the need for adaptive strategies to address seasonal demand variations.
- Emphasizes prioritizing underutilized MSAs to optimize infrastructure and build a sustainable RAM network.

Thank You