The Impact of Rail Station Accessibility on Competitiveness of Rail Services: Insights from a Multi-stage Game Theoretic Model

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PRESENTATION AT THE JOINT SEMINAR WEEK AT IUT
APRIL 4, 2019

Motivation

- Conventional Amtrak, HrSR, and HSR, will coexist in the future intercity passenger rail market
- Different technologies: different operating costs
- Rail faces major competition from commercial aviation and bus services in intercity travel market
- Rail can gain its advantage in total travel time by providing convenient access to train stations
- Rail agency ownership: pure profit maximizer → pure social welfare maximizer

Motivation

- A three-stage game-theoretic model to answer:
  - What train technology would be the optimal decision for the rail agency?
  - How does rail access time affect the competitiveness of rail in the intercity travel market?
  - To what extent the rail agency's private/public objectives affect rail fare, frequency, and market share?
- Intercity corridors with one rail agency and one airline (corridors connecting between a city which is an airline's hub and a spoke city)
- HrSR/HSR infrastructure is available

The model

- Three stage gaming model
  - Backward induction is adopted to solve the problem
- Equilibrium prices and service frequencies are determined
- Rail objective: $O_r = (1-\theta)\pi_r + \theta CS_r$

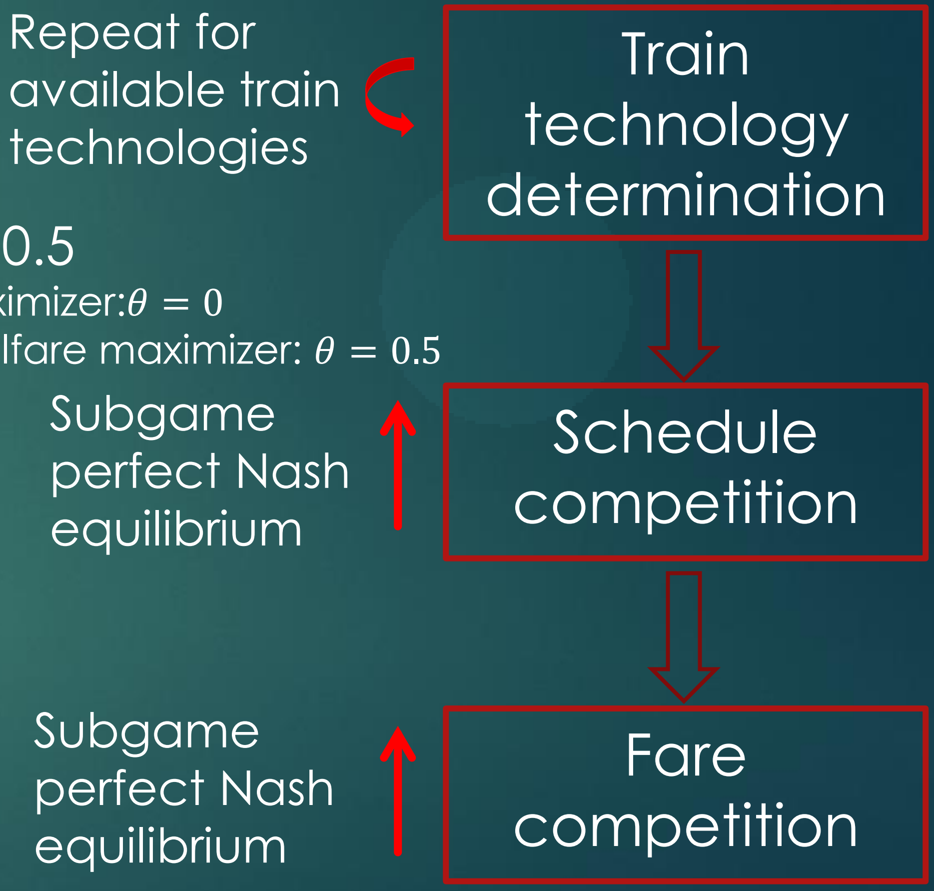
$(1-\theta)\pi_r$ → Profit

θCS_r → Consumer surplus

$0 \leq \theta \leq 0.5$

Profit maximizer: $\theta = 0$

Social welfare maximizer: $\theta = 0.5$



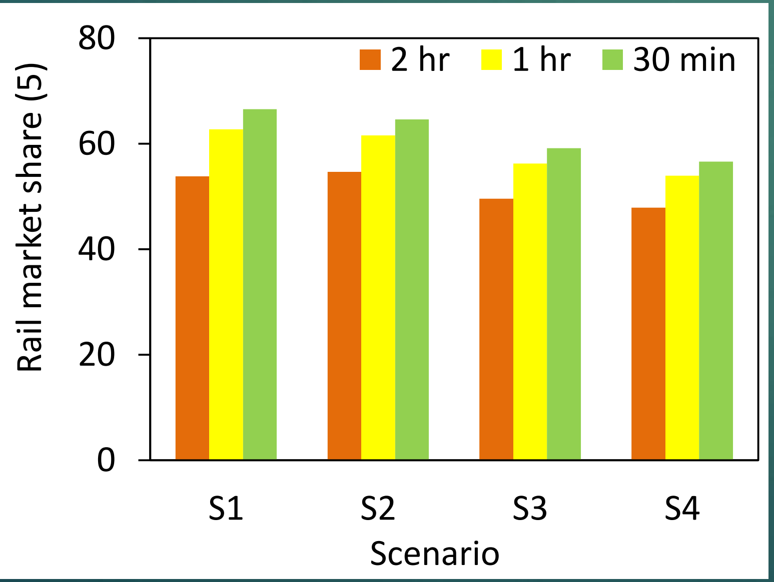
Application

- Three different technologies, including conventional rail, HrSR, and HSR, for each corri

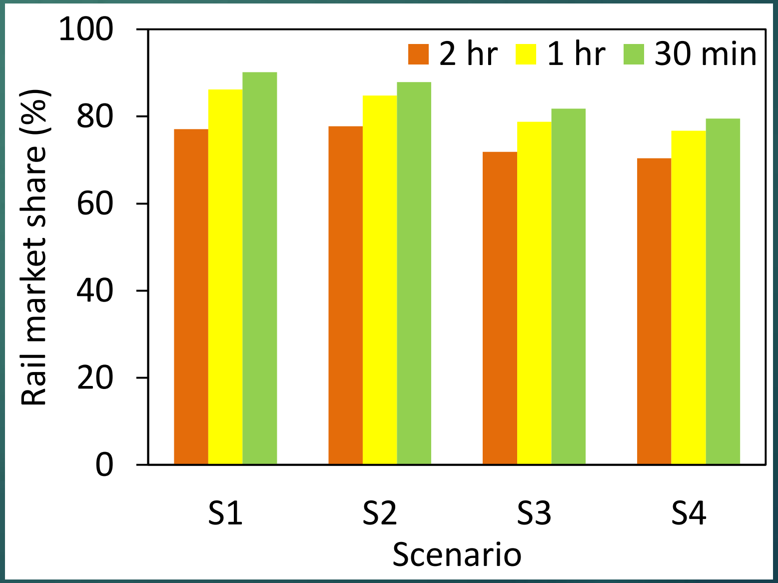
Scenario	Corridor
1	Chicago-St. Louis
2	Chicago-Cleveland
3	Chicago-Minneapolis
4	Chicago-Omaha

Rail station accessibility

- Impact of rail access/egress time
  - HSR may become unattractive if the origin and/or destination station is outside a city's downtown
  - Greater rail market share as station access time decreases
  - The variation is about 6-9% for 1 hr increase of rail access time



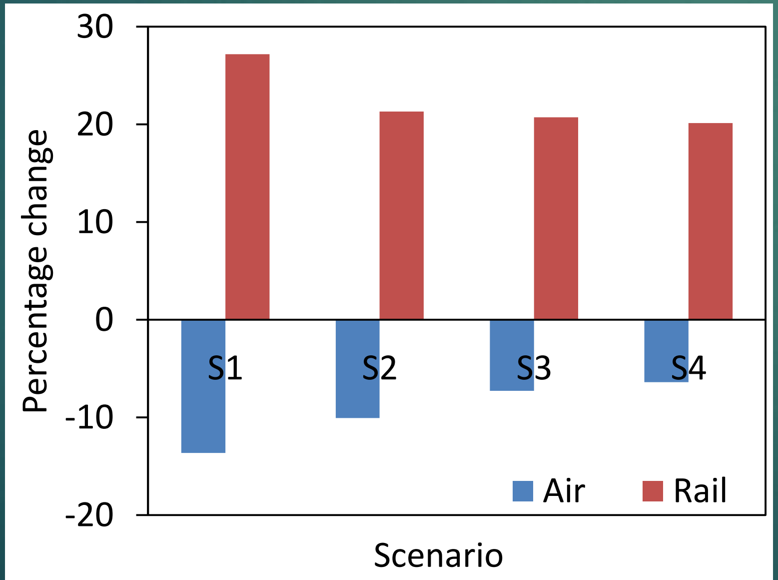
$\theta = 0$



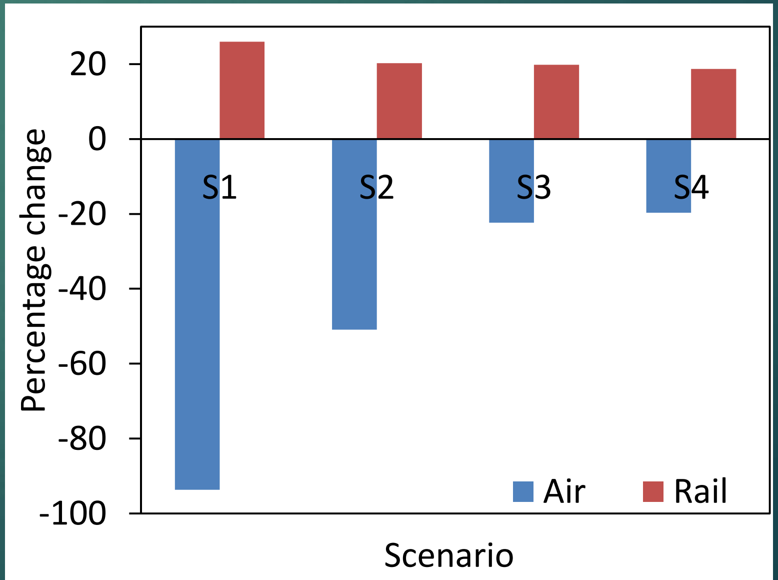
$\theta = 0.5$

Rail station accessibility

- Impact of rail access/egress time
  - The extent of change in the rail objective value diminishes with distance
  - The percentage change in airline profit is less significant when $\theta = 0$



$\theta = 0$



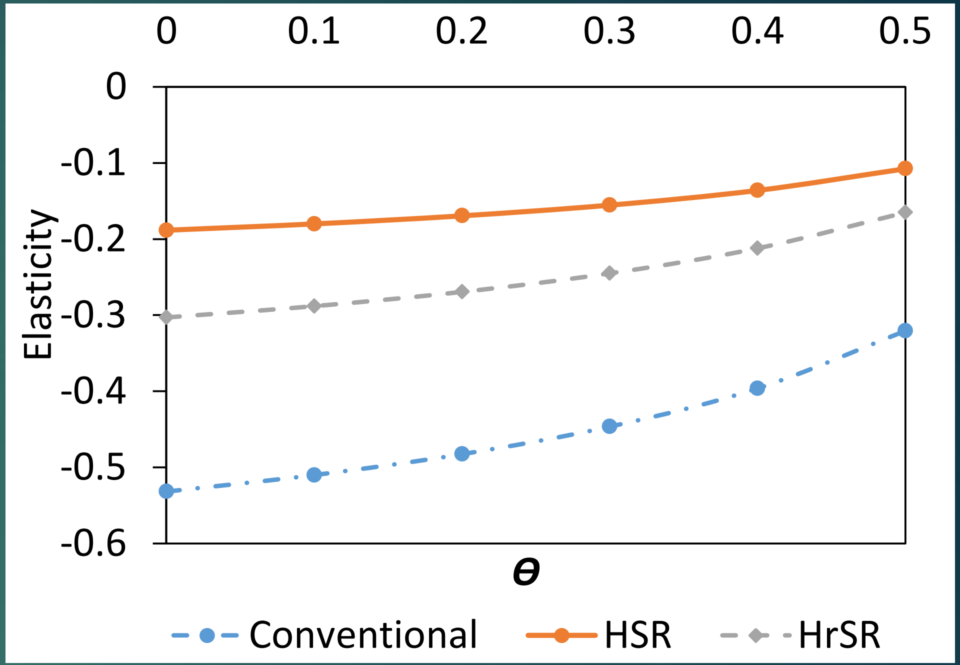
$\theta = 0.5$

Rail station accessibility

- Elasticity of demand: a measure of the sensitivity of demand function with respect to changes in a certain variable (e.g., price and access time)
- Example: if price elasticity of rail demand is -1.2, 5% increase in rail fare will reduces demand by 6% (-1.2*5 = -6%)

Rail station accessibility

- Elasticities vary between -0.53 and -0.1
- Absolute value of elasticity reduces with train speed: as we increase speed we can care less about access time to the rail station
- Absolute value of elasticity reduces with θ: a private rail agency should care more about the location of the station



Policy insights

- Reducing rail station access time considerably impacts rail objective. The impact diminishes with the corridor distance
- The considerable benefits gained from running a public rail agency could mean reduced, or even negative, profit which necessitates governmental subsidies
- The operational advantage of HSR over HrSR and conventional rail needs to be weighed against its usually greater costs associated with infrastructure investment

Thank you for your attention!

Questions?

Talebian, A., and Zou, B. (2018). A multi-stage approach to air-rail competition: Focus on rail agency objective, train technology and station access. Journal of Rail Transport Planning & Management 6(1), 48-66.

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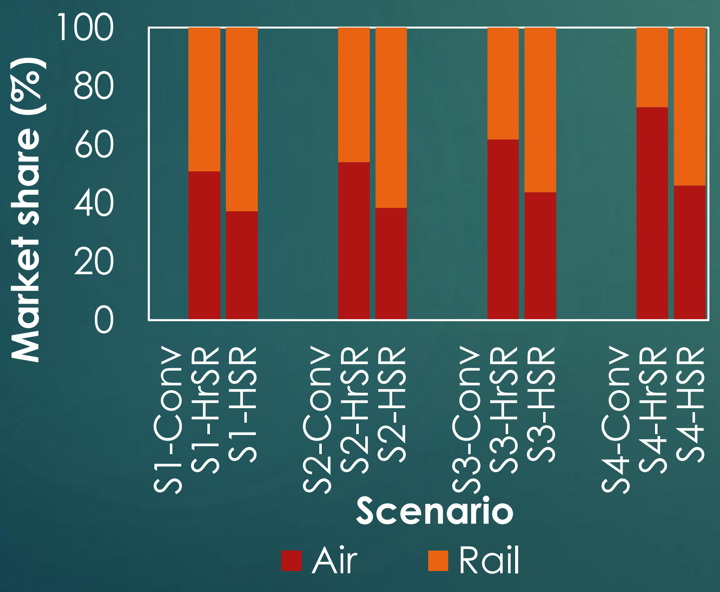
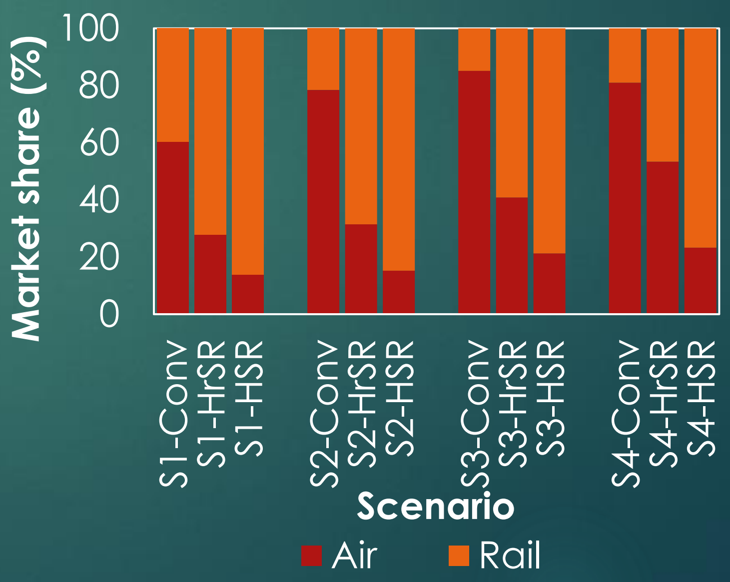
Backup slides

Numerical analysis

- Market shares
  - The conventional rail → HrSR → HSR conversion leads to greater rail market share
  - When $\theta = 0.5$, the extent of market share increase is generally over 100% from conventional rail to HSR



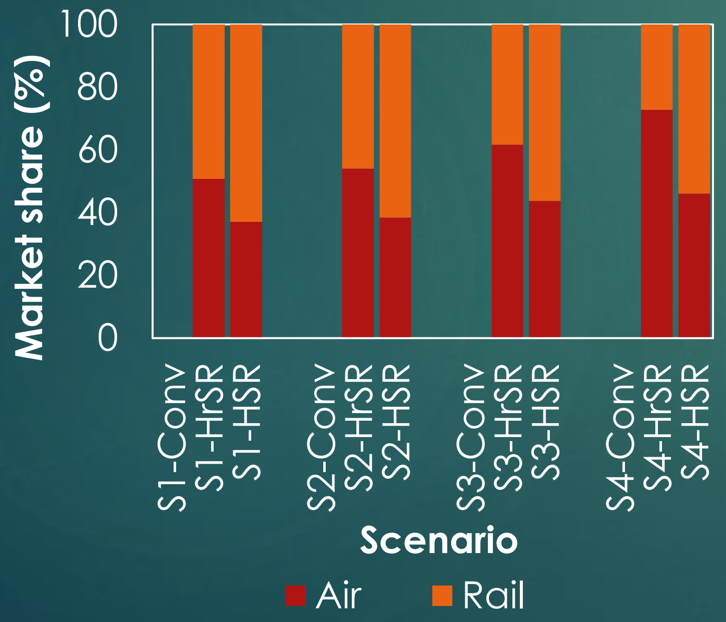
$\theta = 0$



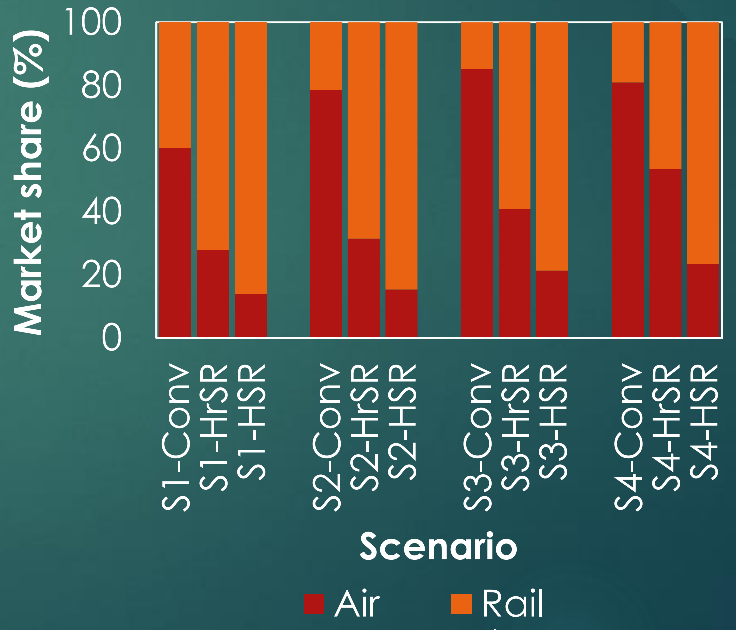
$\theta = 0.5$

Numerical analysis

- Market shares
  - Maximizing social welfare put more emphasis on attracting passengers, resulting in greater rail market share
  - Rail would become the dominant mode when $\theta = 0.5$



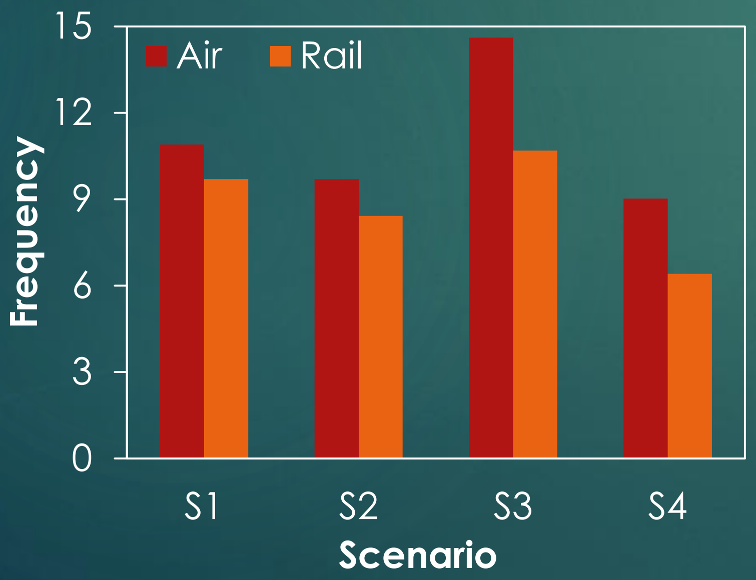
$\theta = 0$



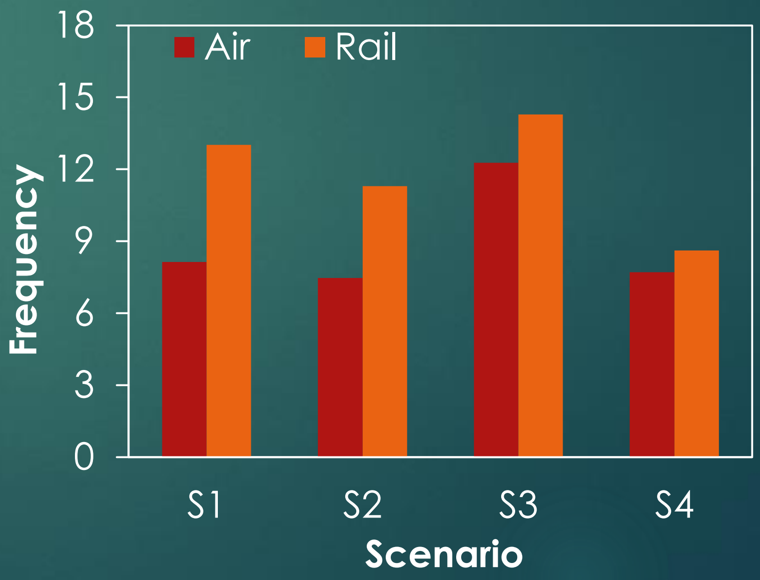
$\theta = 0.5$

Numerical analysis

- Frequency response
  - When $\theta = 0$, the equilibrium frequencies of rail and air are generally comparable for scenarios 1, 2, and 4, ranging from 6 to 11 per day
  - If $\theta = 0.5$, rail frequency will increase. The competition pressure also prompts the airline to adjust frequency



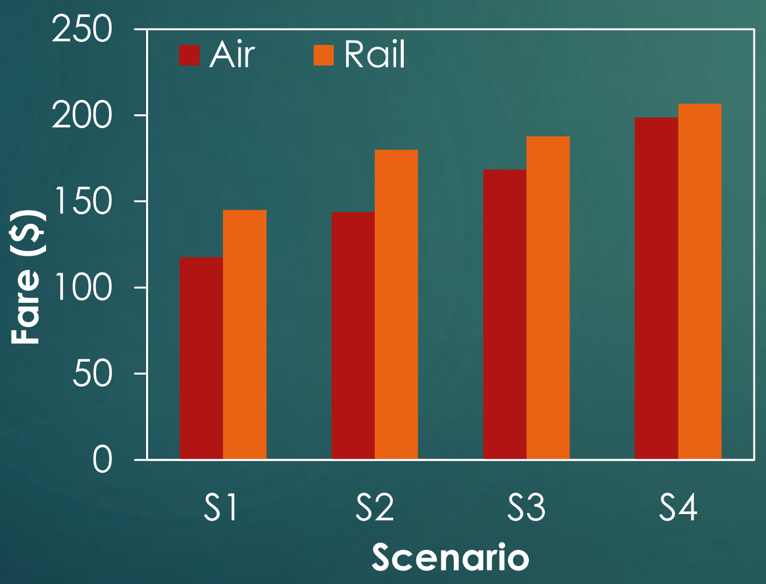
$\theta = 0$



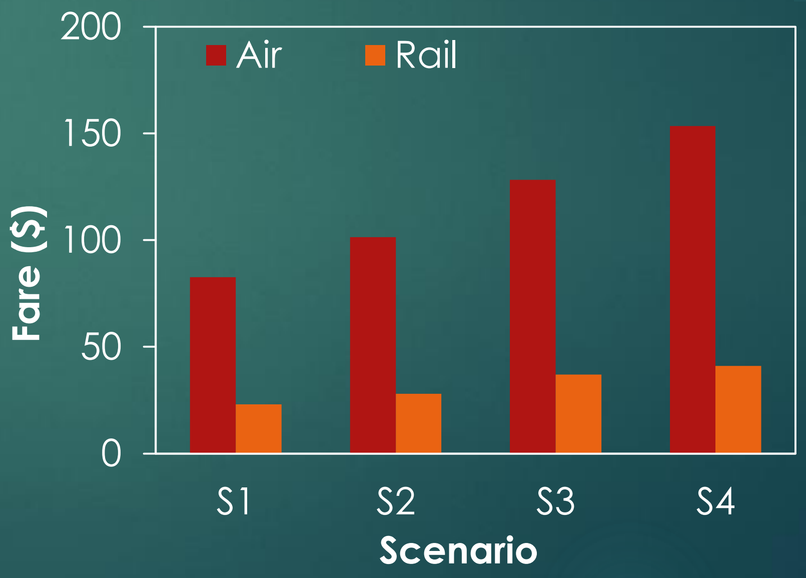
$\theta = 0.5$

Numerical analysis

- Fare response
  - When θ=0, rail and air fares are very close to each other
  - If maximizing social welfare becomes the objective, then rail fare will substantially decrease



$\theta = 0$



$\theta = 0.5$

Numerical analysis

- Induced demand
  - Increasing the θ value, leads to 92% increase in rail demand
  - Overall system demand increase is also significant, by more than 40% between $\theta = 0$ and $\theta = 0.5$