Transportation Network Modeling in NETPLAN

Passenger Transportation

Venkat Krishnan
Eirini Kastrouni
Jeff von Brown
Steve Lavrenz
Konstantina Gkritza
James McCalley

NETSCORE Meeting
March 05 2012
Outline

1. Introduction to NETPLAN
2. Transportation modeling- A review
   - Freight
   - Passenger
3. Developed model of Passenger Network
   - Model to emulate mode competition
   - Infrastructure sharing by fleet
4. Data Development – Eirini’s presentation
   - Passenger network topology
   - Data collection
5. Simulation Results
6. Summary & Future work
A modeling framework capable of representing the operation and investment of the energy and transportation systems
Energy system modeling for cost minimization model

• Generalized flow transportation model
• Commodity: energy
• Paths
  – Electric transmission
  – Gas pipelines
  – Liquid fuel pipelines
  – Conversion
• Decision variables
  – Flow across the system
  – Capacity investment in arcs

• Generation – 15 technologies
• Attributes
  – Investment
    • Cost
    • Lifespan
    • Capacity value
  – Operational
    • Cost (fuel, emission)
    • Emissions
    • Capacity Factor
    • Ramp rates
    • Variability induced
Transportation modeling - REVIEW

- **Multicommodity flow**
  - Coal, cereal grains, foodstuffs, chemicals, gravel, wood, passengers
  - Arc/nodal demand- forecasted or induced
  - Arc (Routes) fixed
- **Infrastructure**
  - Highway, railway, waterways, airports
- **Fleet**
  - Trucks, Cars (hybrid and gasoline)
  - Trains (electric and diesel)
  - Barges
  - Planes
- **Decision Variables**
  - Amount of each arc’s freight allocated to each possible mode
  - Amount of each node’s vehicle allocated to each possible mode
  - Investment on infrastructure and fleet

- **Attributes**
  - Investment
    - Cost
    - Lifespan
  - Operational
    - Cost (fuel, time)
    - Emissions
    - Fleet Capacity - occupancy
    - Vehicle usage
## Transportation in NETPLAN-Freight

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Fleet/ fuel</th>
<th>Infrastructure</th>
<th>Demand</th>
<th>Decision Variables</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight</td>
<td></td>
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<tr>
<td>1. Coal</td>
<td>Truck/ diesel</td>
<td>Highway</td>
<td>Node/Arc based (k-ton/year)</td>
<td>Mode allocation</td>
<td>Arc-demand Modeled</td>
</tr>
<tr>
<td>2. Non-coal</td>
<td>Train/ diesel</td>
<td>Railway</td>
<td>1. Induced 2. Forecasted</td>
<td>Fleet/Infrastructure investment</td>
<td>Node-demand Not Accounted</td>
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### Diagram

- **Investments $/k-ton h**
- **M$/M gallon**
- **M gallon/k-ton-mile**
- **k-ton/year**
- **nTAB**
- **n = 1,2,3,4,5 (non-coal)**

- **CO2/M gallon**
- **XD**
- **DD**
- **train**
- **truck**
- **highway**
- **railway**
- **A**
- **B**
Transportation in NETPLAN-Passenger

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<tbody>
<tr>
<td>Personal vehicles</td>
<td>Cars/ Gasoline &amp; electricity</td>
<td>Highway (charging stations)</td>
<td>Node based</td>
<td>- Vehicle allocation</td>
<td>- Modeled (infrastructure not taken into account)</td>
</tr>
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<td></td>
<td></td>
<td>Forecasted (vehicles/year)</td>
<td>- Fleet investment</td>
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Commodity Costs:
- M$/M gallon
- M gallon/vehicle-mile
- CO2/M gallon
- GWh/vehicle-mile
- Investments $/vehicle
- VDxx #vehicles/year
Transportation in NETPLAN-Passenger fleet not represented

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<td>- Passengers</td>
<td>Planes/ Gasoline Train/ electricity</td>
<td>Airport (gates) HS rail tracks</td>
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Why important?
1. Bulk portion of passenger transportation need met by such dedicated modes
2. Interesting to capture competition between these fleet
3. Interesting research questions investigated:
   • To what extent can electric high-speed rail reduce energy use and transportation-related emissions while competing with air and highway travel?
   • What is the impact of moving x% transportation demand from one mode to another
   • Passenger transportation resiliency...
Developed Passenger Network – Arc based model to emulate mode competition

#trips = #vehicle * VUF (vehicle usage factor)
VUF ~ function of link distance
η = fleet capacity (passengers/vehicle)
Investments – affects fleet load sharing capacity

1. Fleet
   - \#trips = \#vehicle * VUF (vehicle usage factor)

2. Infrastructure → maximum trips per year
   - Air: \#trips (inbound) α available gates/terminals
   - Highway, rail (conventional or HSR) – investments in lane or tracks increase maximum trips per year
Vehicle Usage factor

- Similar to capacity factor in electric sector (for long term planning in the absence of markets)
- Function of link/arc distance:
  - Diesel train
    - 1 trip per day
  - Diesel truck
    - 1-250 miles – 1 trip per day
    - 250-500 miles – 1 trip per two days
    - >500 miles – 1 trip per three days
  - Planes
    - 1-500 miles – 3 trips per day
    - 500-1000 miles – 2 trips per day
    - >1000 miles – 1 trip per day
  - HSR
    - 1-100 miles – 3 trips per day
    - 100-300 miles – 2 trips per day
    - >600 miles – 1 trip a day
  - Cars
    - 1-150 miles – 1 trip per day
    - 150-500 miles – 1 trip per month
    - >500 miles – 1 trip per 6 months
Transportation Network
Infrastructure sharing by fleet

Freight A
- Railway
  - Diesel Train
  - Freight B

Passenger A
- Highway
  - Diesel Truck
  - Car (G/H)
- Air
  - Plane
- High Speed Rail
  - Electric Train

Passenger B

Highway sharing → need units matched...
Freight model revisited - revised

 Investments
 $/vehicle
 $/infrastructure

#trips * η

#trips = #vehicle * VUF (vehicle usage factor)
VUF ~ function of link distance
η = fleet capacity (k-tons/vehicle)
Passenger Network data development
Simulation Results

• Case specification
  • Passenger arcs - 235
  • Freight arcs – 96

• **Case 1:** Infrastructure investment cost not considered – infinite infrastructure

• **Case 2:** Infrastructure investment cost considered only for HSR
Passenger vehicles investments

Case 1: 331543 TWh
Case 2: 329756 TWh
0.5% extra energy consumption
CO$_2$ Emissions

Case 1

Case 2

EmCO2Pass

EmCO2Pass
# Summary of Transportation sector in NETPLAN

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- Personal vehicles
- Passengers
Future work

1. Time value monetized with operational cost
2. Intra-region dedicated freight/passenger vehicle demand
3. Infrastructure investment – to increase fleet operating limits
4. Case studies
Thank You