Transportation Systems Analysis

Tom Mathew
Goal of Transportation

What is transportation?

What are its characteristics?
What is transportation?

- Road construction?
What is transportation?

• Logistics?
What is transportation?

- Traffic control?
What is transportation?

- Traffic control?
What is transportation?

- Solving congestion?
What is transportation?

- **Solving congestion?**
What is transportation?

• Reducing accidents?
What is transportation?

• Confusing!
  – Road construction
  – Logistic
  – Traffic control
  – Solving congestion
  – Accidents
  – …
What are its characteristics?

- **Multi-modal**
What are its characteristics?

- **Multi-sector**
- Government
- Operator
- User
- Public
What are its characteristics?

- **Multi-problem**
  - national and international policy
  - location and design of specific facilities
  - regulatory, institutional, and financial policies
What are its characteristics?

• Multi-disciplinary
  – Engineering
  – Economics
  – Operations research
  – Psychology
  – Social sciences
  – Management
  – Law
What are its characteristics?

• **Planning context**
  – Long/short range planning
  – Passenger/Freight transport
  – International transport
What are its characteristics?

• Changing Background
  – Changes in the demand
  – Changes in the technology
  – Changes in operational policy
  – Changes in values of the public
What are its characteristics?

• **Complex!**
  – Multi-modal
  – Multi-sector
  – Multi-problem
  – Multi-objective
  – Multi-disciplinary
  – Planning context
  – Changing background
Goal of Transportation

• **Diversity in**
  
  – Problem domains!

  – Solution methodologies!

• **Unifying Theme**

  – *Goal of Transportation*
Goal of Transportation

To intervene, delicately and deliberately in the complex fabric of society to use transport effectively in coordination with other public and private actions to achieve the goals of that society

Prof. Manheim, MIT
Implications of the Goal

• **Two assumptions**

1. Total transportation system must be viewed as a single *multi-modal* system

2. Transportation system considerations are *inseparably* related to the social, economic, and political activity of the region
Implications of the Goal

• Four analysis steps

1. Consider all modes of transportation
2. Consider all elements of transportation
3. Consider all movements
4. Consider total trips

What are we doing here?
Role of transportation professional

Flow Prediction

Prediction of Associated Impacts

How do we formally do this?
Transportation-Activity-Flow System
Defining **TAF** System

T  Transportation system

A  Socio-economic activity system

F  Flow pattern
Defining TAF System

T Transportation system
different modes facilities like highways, etc.

A Socio-economic activity system
all social, economic, political, and other transactions (work, land-use, housing, schools, etc.) taking place in a given region

F Flow pattern
includes O-D, routes, volume or passenger/goods, etc.
Intervening TAF system

Transport Options
- Technology
- Network
- Links
- Vehicles
- Operations
- Policy

Activity Options
- Travel
- Other options

Impacts
- User
- Operator
- Government
- Physical
- Functional

TAF System

Diagram showing the interactions between transport options, activity options, and impacts on the TAF system.
Relations in TAF system

- **Three kinds of relationships**

1. The $F$ is determined by $T$ and $A$

2. Current $F$ will cause changes in $A$ over a period of time

3. Current $F$ will also cause changes in $T$ over a period of time
(1) $F$ is determined by $T$ and $A$

(2) Current $F$ will cause changes in $A$ over a period of time

(3) Current $F$ will cause changes in $T$ over a period of time
Changes in TAF system

• Consider

  – Current transportation system T
  – Current activity system A
  – Changes in T and A

\[ T' = T \pm \Delta T \]

\[ A' = A \pm \Delta A \]

\[ F \rightarrow F' \]
Changes in TAF system

$T' = T + dT$

$A' = A + dA$

$F'$ ?
Flow prediction in **T-A-F** System

Supply and demand function

Existence of equilibrium
T implies a Supply function $f_j$
Demand function

- A implies a demand function $f_d$
Existence of equilibrium

- Supply function $f_j$ given $T$
  \[ S = f_j(T, V) \]

- Demand function $f_d$ given $A$
  \[ V = f_d(A, S) \]

- Existence of equilibrium flow $F$
  - Flow $F$ implies $F = (V, S)$
    - Volume $V$ using the system
    - Associated level of service $S$
Existence of equilibrium

\[ S = f_j(T, V) \]

\[ F = (V, S) \]

\[ V = f_d(A, S) \]
Transportation intervention

Introduction of new facility
Activity changes in future

New facility and activity changes

[Graph with axes and curves labeled S(t), S^2, S^0, V_0, V^2, F_j, F_j^2, F_d, F_d^2, T, A constant]
Numerical Example

Refer Notes Also
Numerical example

Consider a highway connecting city 1 and 2. The minimum travel time is 15 units and it increases by 0.1 units for every unit increase of the volume.

The maximum demand for travel is 5000 trips and demand decreases by 100 units for every unit increase in travel time. What will be the current flow and the travel time on the road?

In future, the will be widened which may result in minimum travel time of 10 units, and it increases by 0.05 units for every unit increase of the volume. What will be the future flow and the travel time on the road?
Numerical example

- **Solution**
  - Base travel time function: \( t = 15 + 0.1v \)
  - Base demand function is: \( v = 5000 - 100t \)
  - Future travel time function: \( t' = 10 + 0.05v \)
  - Current flow and travel time
    - ?
  - Future flow and travel time
    - ?
Home work

– Select a current transportation issue that interests you and that involves a particular service or operator

– Identify all the elements of (a) Transport system (b) Activity system that are of interest

– What could be a (i) Supply function and (ii) demand function

– Propose how the activity system and transport system may change, thereby affecting Supply and demand functions
Economics

Does this modeling reminds you anything you have studied earlier?
Law of demand

Higher the price, lower quantity is desired
Law of supply

Higher the price, higher quantity is supplied
Demand supply equilibrium

Price

Quantity

Demand supply equilibrium
Transportation

Law of demand

Higher the cost of travel, demand for travel is less

Cost of travel

Volume (Trips)
Law of supply

Higher the volume, higher will be the cost of travel
How many will travel?
At what cost?
Conclusion

• **Core of Transportation Analysis**
  
  – Establishing relationship between TAF
  
  – Project changes in Activity
  
  – Propose changes in Transportation
  
  – Predict resulting Flows
  
  – And the associated Impact
Conclusion

- **Challenge**
  - Defining $T, A, f_j, f_d$
  - How do we do in reality?
  - Answer Travel Demand Model
Overview of Travel Demand Modeling

**By Survey**

- Input: Base year data
  - Trip generation
  - Trip distribution
  - Model split
  - Trip assignment

**Output: Base Year Link Flows**

- Verifiable

**By projection**

- Input: HORIZON YEAR data
  - Trip generation
  - Trip distribution
  - Model split
  - Trip assignment

**Output: Horizon Link Flows**

- Output for design
Thank You

Questions ?

Reference