PUBLIC TRANSPORTATION NETWORKS

Outline

- A Framework for Improving Connectivity[1]
- Network Structure
- Approaches to Network Design

[1] *Crockett, C., "A Process for Improving Transit Service Connectivity," MST (Master of Science in Transportation) Thesis, MIT, September 2002.*

INTRODUCTION

- Interchanges/Transfers are a basic characteristic of public transport
- They are necessary for area coverage
  - typically 30-60% of urban public transport trips involve 2 (or more) public transport vehicles
- A major source of customer dis-satisfaction contributing:
  - uncertainty
  - discomfort
  - waiting time
  - cost
- Often ignored in service evaluation and planning practice

A Framework For Improving Connectivity

Service connectivity is affected by:

- System elements
- Transfer facility elements
- Service elements

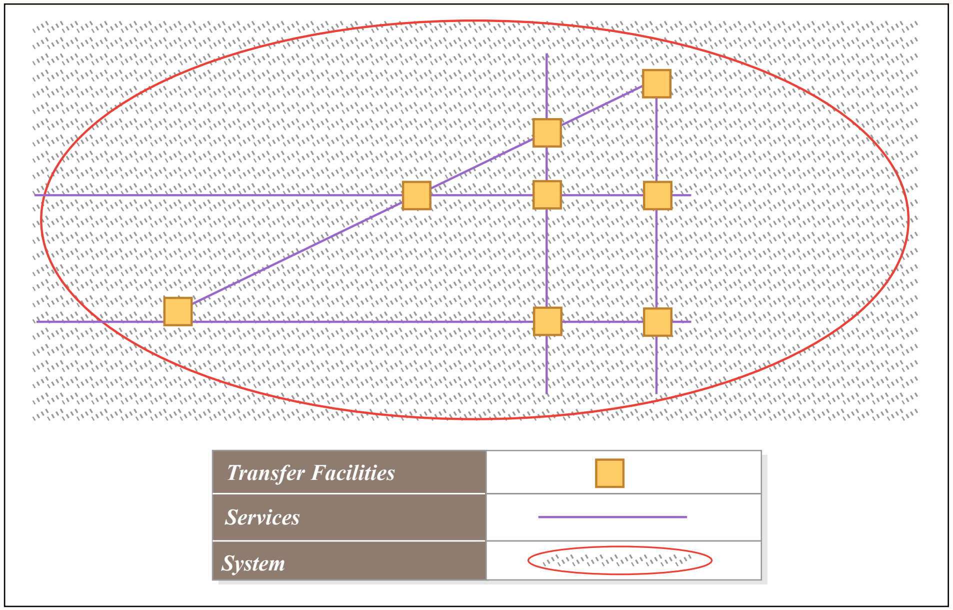


Figure by MIT OpenCourseWare.

System Elements

Transfer Price	Pre-Trip Information	Fare Media	In-Vehicle Information	Fare Control
Free	System information with trip planner	Same	Real-time and connecting route information; transfer announcements	No validation needed, and can leave public transportation space
Discounted	System information		Connecting route information, transfer announcements	No validation needed if remaining in public transportation space
	Route information		Connecting route information	Validation needed, but no delay added to trip
Full additional fare	No information	Different	No information	Validation adds delay to trip

Transfer Facility Elements

Weather protection	**En-Route information**	**Changing Levels**	**Road Crossings**	**Walking Distance**	**Concessions**
Fully-protected connection	Real-time, system, facility, and schedule information	No vertical separation	No road crossing required	No walking required	Large selection
Covered connection	System, facility, and schedule information				
Covered waiting area	Facility and schedule information	Vertical separation with assistance	Road crossing required, but assisted	Short walk required	Small selection
	Schedule information				
Open waiting area	No information	Vertical separation without assistance	Unassisted road crossing	Long walk required	None

Service Elements

Transfer Waiting Time	Span of Service
High frequency	Matched
Matched headways and coordinated arrivals and departures	
Coordinated arrivals and departure	
No coordination	Unmatched

Comparison of Network Structures

RADIAL (with limited circumferential)

Aim: obtain large share of trips to central business district (CBD)

Observations:

- transit has strongest competitive position w.r.t. auto for CBD:
  - high parking prices
  - limited parking availability
  - auto congestion on radial arterials
- CBD market has been declining share of all urban trips
- network effectiveness for non-CBD trips is poor

Conclusions:

- effectiveness depends on specifics of urban area:
  - strength of CBD as generator
  - highway/auto/parking characteristics
- overall level of transit ridership
- political considerations

Grid And Timed Transfer

Aims:

- provide reasonable level of transit service for many O-D pairs
- decrease the perception of transfers as major disincentive for riders

Observations:

- must avoid negative impact on CBD ridership
- what is impact of restricting headways to set figure e.g. 30 min.?
- how much extra running time is required to guarantee connections?
- will transit be competitive in non-CBD markets?
- well-located transfer centers can enhance suburban mobility

Grid And Timed Transfer

Conclusions:

- grid systems work well with high ridership and dispersed travel patterns -- New York City, Toronto, Los Angeles (key here is that high frequencies reduce need for timed transfers)
- timed transfers work well for urban areas with dispersed focused suburban activity centers, multi-modal networks

Pulse

Aim: to provide convenient one transfer service throughout small urban area

Observations:

- route design geared to particular round trip travel time because all routes have same headway
- as number of routes increase, harder to maintain reliability, have to increase recovery/rendezvous time
- depends on availability of effective pulse point

Conclusions:

- well suited for many well focused outer suburban areas and small independent cities

Multimodal

Aim: to provide effective service for both short and long trips

Observations:

- rail (or other guideway) networks are expensive to build and hence network is limited in length
- rail capacity is high, marginal cost of carrying passengers relatively low
- key issues for new rail lines: to what extent is direct bus service retained as opposed to forcing transfer to rail

Conclusions:

- need to look at total trip time and cost to determine net impact on different O-D trips
- build integrated bus/rail fare policy to encourage riders to take fastest route

Approaches to Network Design

1. **Idealized Analysis:**
    - broad strategic decisions
2. **Computer Simulation:**
    - detailed analysis tool
3. **Incremental Improvements:**
    - seek opportunities to intervene locally in network
4. **Global Network Design:**
    - synthesize new network
        - fully automated
        - man/machine interaction

Computer Simulation

Aim:

- tool to answer what-if questions

Functions:

1) specify system (e.g., route characteristics) and operating environment
2) model estimates performance -- transit ridership, costs, etc.
3) revise as desire and re-run

Computer Simulation

Examples: EMME/2, MADITUC

- **network analysis package**
  - **EMME/2: multimodal, full equilibrium**
  - **MADITUC: public transporation, fixed transit demand matrix**
- **strong interactive graphics capabilities for network displays travel flows**

Differentiating Features of Bus Network Models

1. **Demand**
   - assumed constant
   - assumed variable based on service design

2. **Objective Function**
   - minimize generalized cost
   - maximize consumer surplus

Differentiating Features of Bus Network Models

3. **Constraints**
    - fleet size
    - operator cost
    - vehicle capacity

4. **Passenger Behavior**
    - system or user optimizing
    - single or multiple path assignment

5. **Solution Technique**
    - partition into route generation and frequency determination

Incremental Improvement

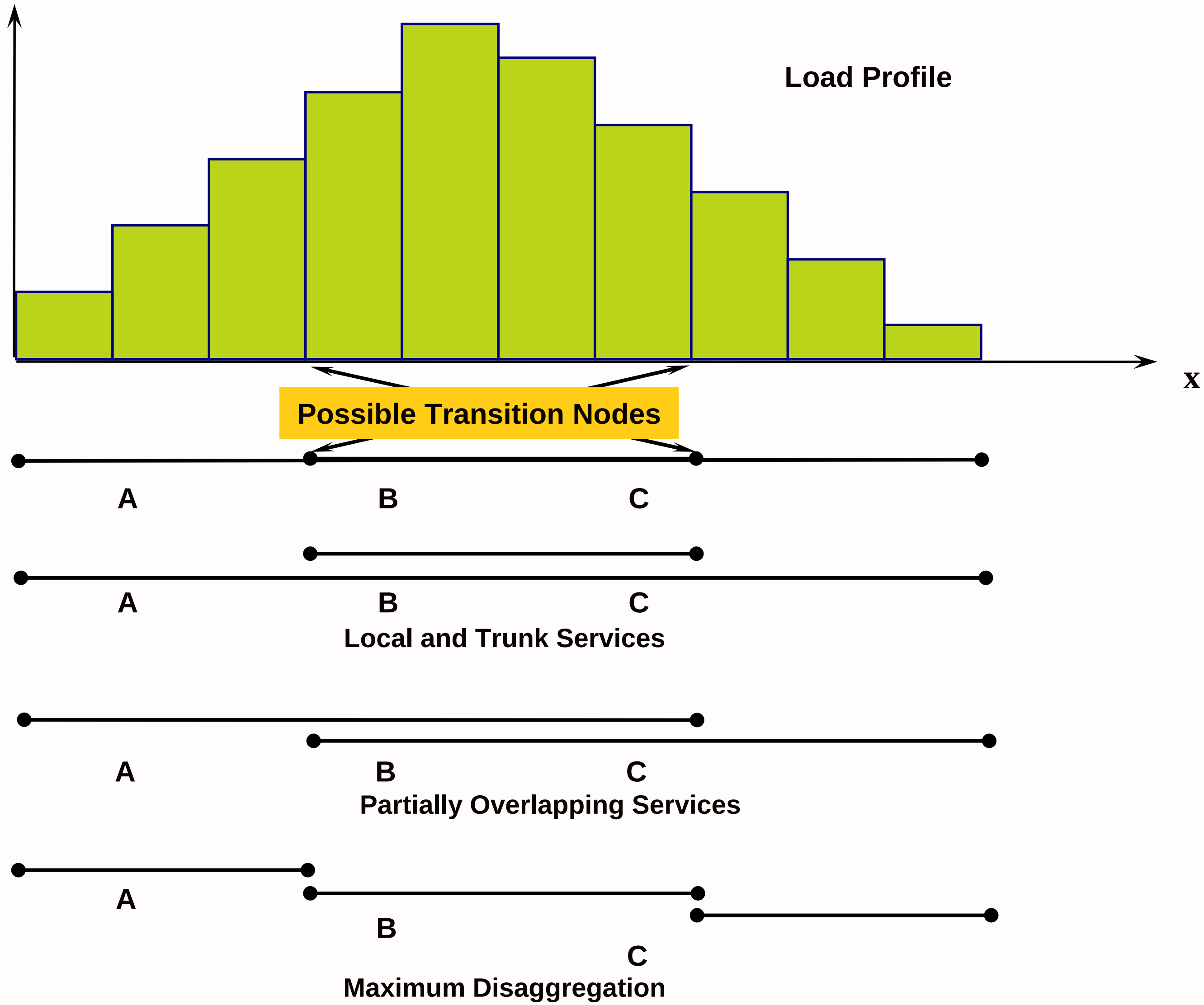
Aim:

- examine load profiles of individual routes looking for improvement opportunities
- obtain routes characterized by high frequencies and fairly constant loads

Strategies:

1) route decomposition: where frequency is high but load is variable along route
2) route aggregation: combine parallel routes to improve frequency or through-route to reduce transfers
3) new services: reduce circuity and operating cost, access new markets

Route Disaggregation Options



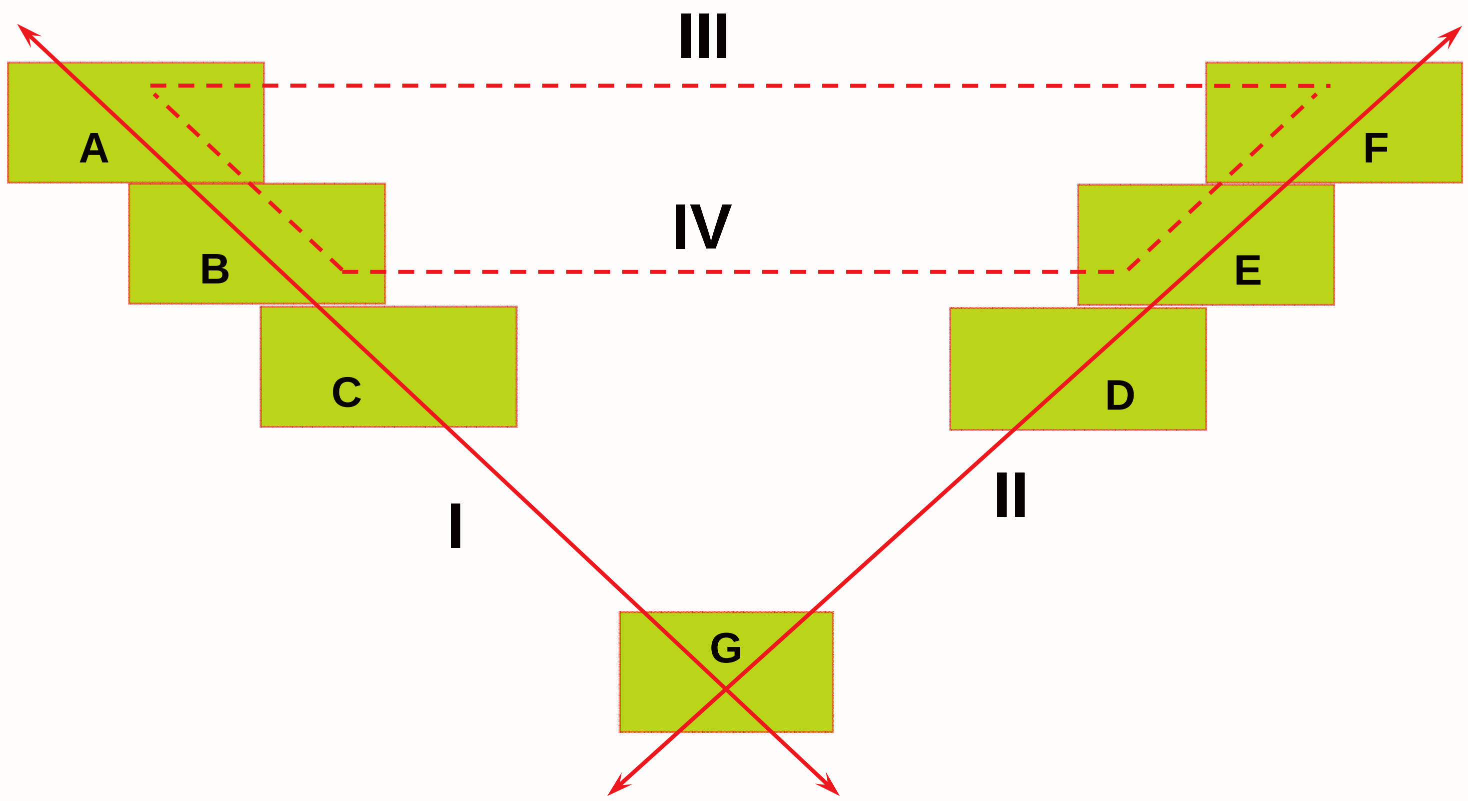
Associated Aggregated O-D Matrix

	A	B	C
A	L/M	L/M	L/M
B	L/M	H	L/M
C	L/M	L/M	L/M

A	L-H	M/H	L
B	M/H	H	M/H
C	L	M/H	L-H

A	L/M	L	L
B	L	H	L
C	L	L	L/M

New Direct Services



VIPS-II Package*

Basic Premises:

- fully automated planning systems won't work
- computer role is to number crunch and organize information
- also solve specific sub-problems
- need interactive graphics for good man-machine communication
- need variable demand

Main Objective:

Maximize number of passengers subject to constraints on:

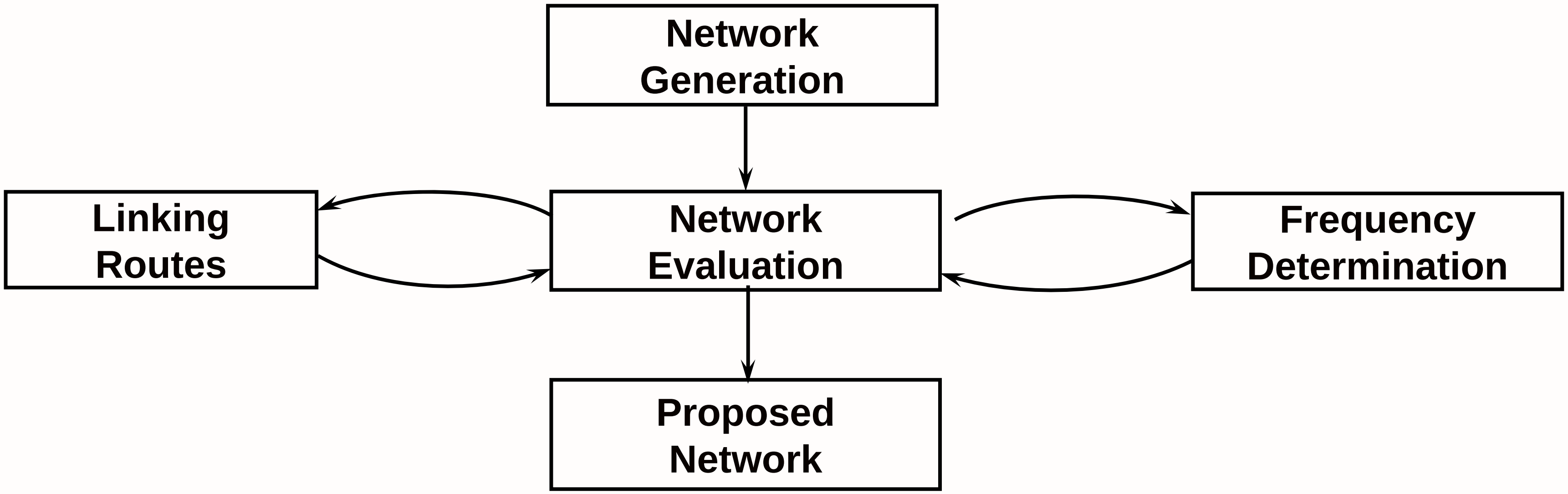
- operator cost
- minimum level of service

**** from "Public Transportation Planning, a Mathematical Programming Approach" by Dick Hasselström. Göteborg, Sweden, 1981.***

General Model Structure

Specific Sub-Problems:

- evaluation of a proposed network
- frequency determination for given routes
- linking routes at junction
- generation of initial route network



NETWORK DESIGN APPROACHES

A) Start with fully connected network and eliminate the weakest routes iteratively, reassigning passenger flows to the best remaining routes

B) i. Start with the following route design principles:

- most high demand O-D pairs should be served directly
- only certain modes are suitable for route termini
- routes should be direct and not be circuitous
- routes should meet to facilitate transfers

ii. Generate a large number of possible routes heuristically

iii. Select final set of routes through optimization problem formulation.