Networks and Route Structure

Outline

- Transfers and network 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.

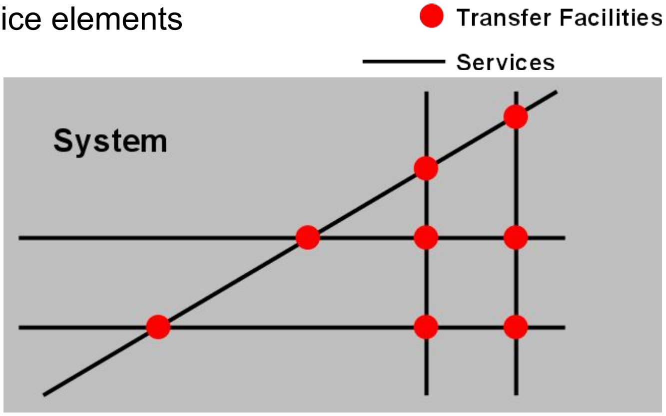
Introduction

- transfers are a basic characteristic of public transport
  - necessary for area coverage
- typically 30-60% of urban public transport trips involve multiple public transport vehicles
- a major source of customer dissatisfaction 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



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

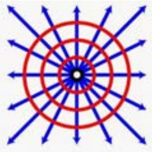
Transfer Facility Elements

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

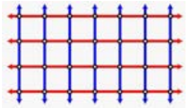
Transfer Waiting Time	**Span of Service**
High frequency	Matched
Matched headways and coordinated arrivals and departures	
Coordinated arrivals and departure	
No coordination	Unmatched

Radial (with limited circumferential)



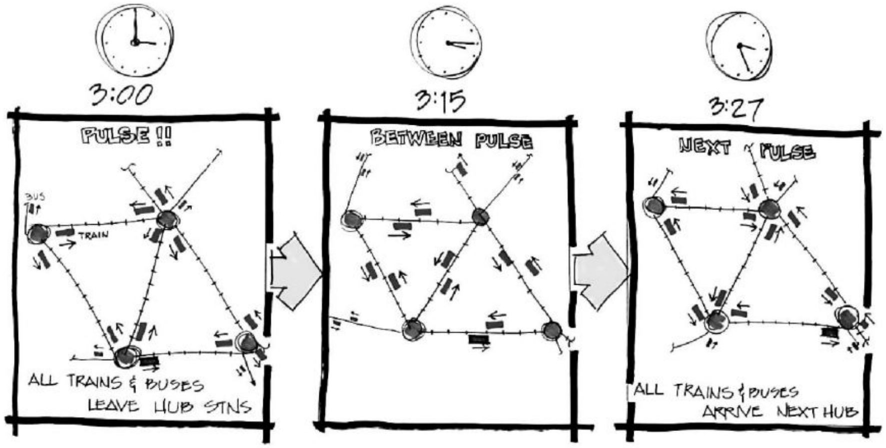
- To obtain large share of trips to city center
- Observations
  - transit has strongest competitive position with respect to auto for CBD
    - high parking prices
    - limited parking availability
    - auto congestion on radial arterials
  - CBD market has been declining share of all urban trips
  - 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

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 minutes?
  - 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
- Conclusions
  - grid systems work well with high ridership and dispersed travel patterns
    - New York City, Toronto, Los Angeles
    - high frequencies reduce need for timed transfers
  - timed transfers work well for urban areas with dispersed focused suburban activity centers, multi-modal networks

Pulse



(a) (b) (c)

Source: Maxwell, R., 2003. Converting a large region to a multimodal pulsed-hub public transport network. *Transportation Research Record: Journal of the Transportation Research Board*, (1835), pp.128-136.

Pulse

- 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
  - making changes to a route becomes difficult, requires coordination
  - not good when there is congestion near pulse point

Multimodal

- 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
  - for new rail lines
    - is direct bus service retained?
    - are passengers forced to 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

- Incremental Improvements
  - seek opportunities to intervene locally in network
  - computer simulation – detailed analysis tool
- Global Network Design – synthesize new network
  - fully automated
  - man/machine interaction

Computer Simulation

- Tool to answer what-if questions
- Functions
  - specify system (e.g., route characteristics) and operating environment
  - model estimates performance – transit ridership, costs, etc.
  - revise as desire and re-run
- Not heavily used for route design, tends to be incremental
- Examples
  - EMME
    - multimodal
    - full equilibrium
  - MADITUC
    - public transportation
    - fixed transit demand matrix
  - strong interactive graphics capabilities for network displays travel flows

Differentiating Features of Bus Network Models

- Demand
  - assumed constant
  - assumed variable based on service design
- Objective Function
  - minimize generalized cost
  - maximize ridership
- Constraints
  - fleet size
  - operating budget
  - vehicle capacity
- Passenger Behavior
  - system or user optimizing
  - single or multiple path assignment
- Solution Technique
  - partition into route generation and frequency determination

Incremental Improvement

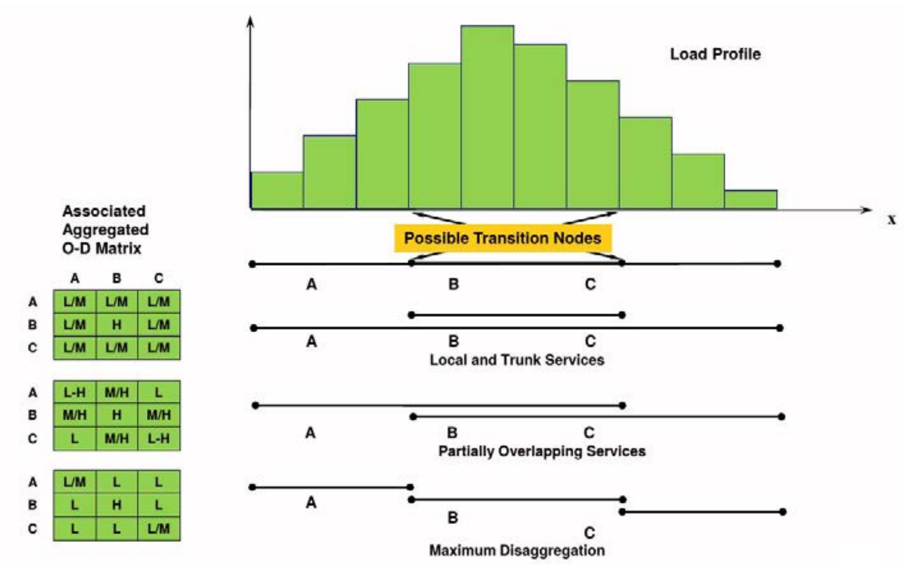
Aims

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

Strategies

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

Route Disaggregation Options

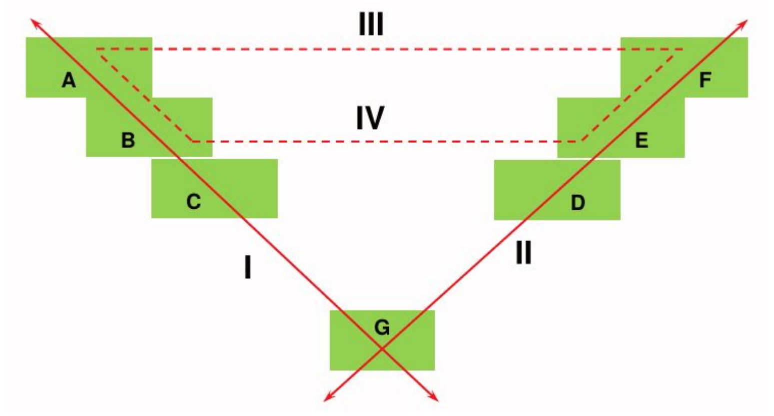


	A	B	C
A	L/M	L/M	L/M
B	L/M	H	L/M
C	L/M	L/M	L/M

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

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

New Direct Services



VIPS-II Package

- Applications
  - route network analysis
  - frequency optimization
- Inputs
  - network
  - fare structure
- Outputs
  - costs
  - revenues
  - productivity
  - travel times
  - level of service
  - route choice

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

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
- Objective
  - Maximize number of passengers subject to constraints
    - operator cost
    - minimum level of service
- 1987 upgrade
  - passengers can be aware/unaware of timetable
  - headways between routes can be coordinated
  - stops and modes can have different disutility weights
  - congestion causes delays and uneven headways

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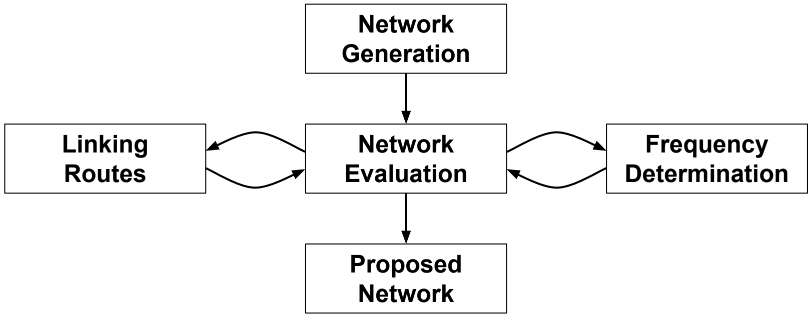
General Model Structure

Specific Sub-Problems

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


Network Generation

Linking Routes

Network Evaluation

Frequency Determination

Proposed Network

Network Design Approaches

- Start with fully connected network
  - eliminate the weakest routes iteratively
  - reassign passenger flows to the best remaining routes
- Generate a large number of possible routes heuristically
  - based on the following route design principles:
    - most high demand O-D pairs should be served directly
    - only certain modes are suitable for route terminal
    - routes should be direct and not be circuitous
    - routes should meet to facilitate transfers
  - Select final set of routes through optimization problem formulation

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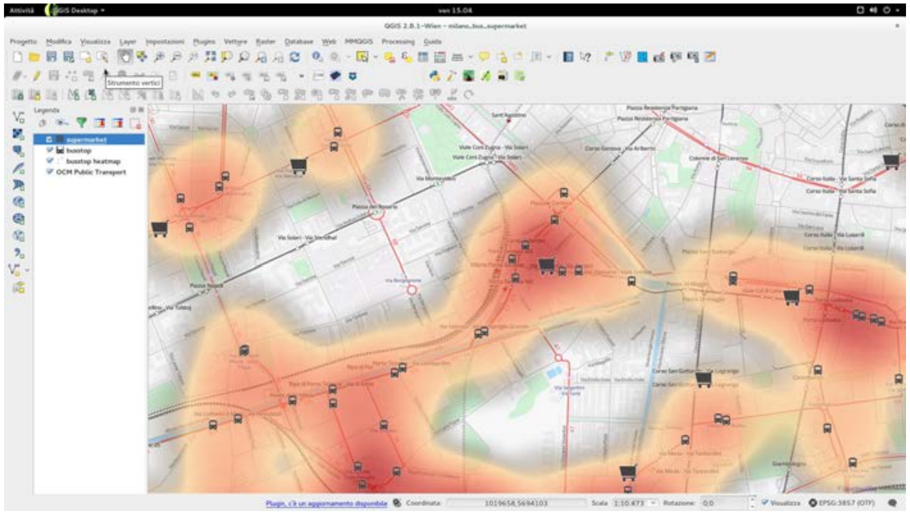
QGIS



Source: https://www.flickr.com/photos/city-planner/16732124571/in/pool-2327386@N22

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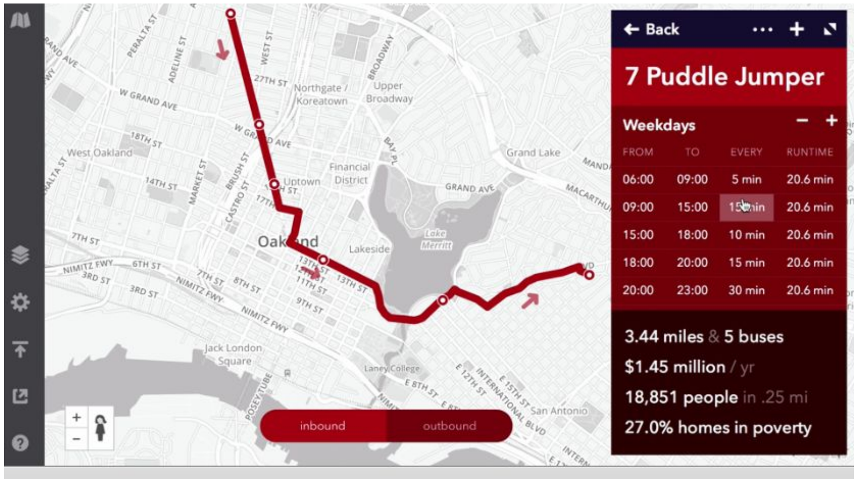

7 Puddle Jumper

FROM	TO	EVERY	RUNTIME
06:00	09:00	5 min	20.6 min
09:00	15:00	15 min	20.6 min
15:00	18:00	10 min	20.6 min
18:00	20:00	15 min	20.6 min
20:00	23:00	30 min	20.6 min

3.44 miles & 5 buses

$1.45 million / yr

18,851 people in .25 mi

27.0% homes in poverty

Source: http://remix.com/

1.258J / 11.541J Public Transportation Systems
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