PUBLIC TRANSPORT MODAL CHARACTERISTICS AND COSTS

Outline

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2. Simple Capacity Analysis
3. World-Wide Status
4. Capital Costs
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2003 US Transit Mode Performance Measures

	Bus	Heavy Rail	Light Rail	Commuter Rail	Paratransit
Unlinked Passenger Trips (x 10^9)	5.7	2.7	.3	.4	.1
Annual Pass-miles (x 10^9)	21.3	13.6	1.5	9.6	.9
Op. Cost/ Rev Veh Hr ($)	92.36	149.69	201.83	384.28	46.73
Op. Cost/Rev Veh Mile ($)	7.28	7.26	12.83	12.12	3.21
Op. Cost/Unlinked Pass Trip ($)	2.67	1.65	2.41	7.75	21.34
Op. Cost/Pass. Mile ($)	.72	.33	.55	.33	2.54
Unl. Pass Trips/ Rev Veh Hr	35.1	90.9	83.4	49.5	2.27
Pass Miles/Rev Veh Hr	129	458	365	1156	18
Mean Trip Length (miles)	3.7	5.1	4.4	23.3	8.4
Mean Pass Load	10.2	22.2	23.24	36.5	1.3
Mean Operating Speed (mph)	12.7	20.6	15.7	31.7	14.5

Ridership Trends by Mode

Mode		2003 Ridership (Millions)	Change 1975-2003 (%)
Metro	- 5 old systems[1] - 6 new systems	2,199 468	575 (+35%)
Light Rail	- 7 old systems - 15 new systems	166 172	42 (+34%)
Commuter Rail	- 4 old systems - 12 new systems	377 33	126 (+49%)
Bus		5,692	-2 (0%)
Total		9,107	1,414 (+18%)

[1] Systems are grouped by metropolitan area

Changes in Service Provided (1993-2003) by Mode

	Active Vehicles	Vehicle Miles Operated
Metro	**+5%**	**+21%**
Light Rail	**+45%**	**+132%**
Commuter Rail	**+17%**	**+28%**
Bus	**+19%**	**+9%**

Service Utilization Trends by Mode

	Boardings/ Vehicle Mile		Avg. Passenger Load	
Mode	2003	% change 1993-2003	2003	% change 1993-2003
Metro	4.2	+8%	22	+10.7%
Light Rail	5.3	-22%	23	-10%
Commuter Rail	1.4	---	36	+8%
Bus	2.3	-3%	10	-5%

Simple Capacity Analysis

Question: **Given a pie-shaped sector corridor serving a CBD served by a single transit line, what will be the peak passenger flow at the CBD?**

Simple Capacity Analysis

Given:

- P_c = population density at CBD
- dP = rate of decrease of population density with distance from CBD
- θ = angle served by corridor
- r = distance out from CBD
- L = corridor length
- t = number of one-way trips per person per day
- c = share of trips inbound to CB
- m = transit market share for CBD-bound trips
- p = share of CBD-bound transit trips in peak hour

Then:

Population in corridor =

$$\int_0^L r\theta\left(P_c - dPR\right)dr$$

=

$$L^2\theta\left(\frac{P_c}{2} - \frac{dPL}{3}\right)$$

Simple Capacity Analysis

Peak Passenger Flow = $L^2\theta\left(\frac{P_c}{2} - \frac{dPL}{3}\right)tcmp$

Maximum access distance to transit line = $L\theta/2$

Examples:

P_c	dP	θ	L	t	c	m	p	Req. Capacity	Max Access
10,000	800	$2\Pi/9$	10	2.5	0.2	0.5	0.25	10,000	3.5
20,000	1,600	$2\Pi/9$	10	1.5	0.3	0.8	0.25	30,000	3.5

Actual Capacities

Rail: 10 car trains, 200 pass/car, 2-minute headway ≡ **60,000 pass/hr**

Bus: 70 pass/bus, 30-second headways ≡ **8,400 pass/hr**

BRT: 200 pass/bus, 20 second headways ≡ **36,000 pass/hr**

Light rail: 150 pass/car, 2-car trains, 1-minute headway ≡ **18,000 pass/hr**

MBTA Rail Line
Peak Hour Volumes

Red Line:	**Braintree branch**	**6,100**
	Ashmont branch	**3,700**
	Cambridge	**8,200**
Orange Line:	**North**	**8,100**
	Southwest	**7,400**
Blue Line:		**6,000**
Green Line:	**B**	**2,000**
	C	**1,900**
	D	**2,200**
	E	**900**
	Central Subway	**6,500**

Worldwide Urban Rail Systems

A. Full Metro Standards

Started system operation	N. America	Europe	Rest of World	Total Starts	Cumulative Starts
Pre 1901	2	5	--	7	7
1901-1920	2	4	1	7	14
1921-1940	--	4	2	6	20
1941-1960	1	5	1	7	27
1961-1980	3	17	12	32	59
1981-2000	3	4	12	19	78
Post-2000 or In Construction	1	7	5	13	91
TOTALS	12	47	32		

B. Light Rail Systems: total in operation

	N. America	Europe	Rest of World	Total
Total Systems	22	50	15	87

Capital Costs

In US:

- **$13.2 billion in capital costs in 2003**

By type:

- **28% for vehicles**
- **57% for infrastructure and facilities**
- **15% other**

By mode:

- **25% for bus projects**
- **34% for metro projects**
- **19% for commuter rail projects**
- **18% for light rail project**
- **4% other**

Capital Costs by Type and by Mode

	Bus	Metro	Commuter Rail	Light Rail	Other
Vehicles	49%	19%	29%	14%	42%
Infrastructure, facilities, and other	51%	81%	71%	86%	58%
Total ($ bill)	3.2	4.4	2.5	2.3	0.8

- Infrastructure, facilities and systems capital costs dominate for rail modes
- Vehicular capital costs represent about half of all capital costs for bus

Infrastructure Costs

Key factors:

- **type of construction**
  -- at grade (least expensive)
  -- elevated
  -- subway: shallow tunnel, deep tunnel (most expensive)
- **land acquisition and clearance**
- **number, size, complexity, and length of stations**
- **systems complexity**

Typical Capital Costs

Metro:

	System cost (includes stations and vehicles) ($ billion)	Cost/km ($ million)
Tren Urbano: new system (2002) Phase I: 17 km, 16 stations 50% at grade, 40% elevated, 10% subway	2.0	118
MBTA Red Line Alewife Station Extension (1984) 5 km, 4 stations: 100% subway	0.6	120
LA MTA: new system (late 1980s) 7 km: subway	1.2	180
WMATA: new system (late 1970s-early 1990s) Multiple phases 100 km, 70 stations (partial system) Mix of subway, elevated, and at grade	6.4	60

Kain (mid-1990s) estimate of average metro capital costs: $80 million/km

Typical Capital Costs (cont'd)

LRT:

	System cost (includes stations and vehicles) ($ million)	Cost/km ($ million)
LA MTA (late 1980s): 30 km, at grade	690	23
Buffalo (late 1980s): 10 km, subway	529	53
Santa Clara (late 1980s): 30 km, at grade	498	16
Portland: 22 km, at grade	214	10

Kain (mid-1990s) estimate of average LRT capital costs:
$25 million/km

Typical Capital Costs (cont'd)

Busways:

	System cost (includes stations) ($ million)	Cost/km ($ million)
MBTA South Boston Transitway (2002): 2 km, bus tunnel	606*	303
Bogotá Transmilenio (2001): 36 km, at grade	200	5
Seattle (mid 1980s): 2 km, bus tunnel	319	160
Pittsburgh (mid 1980s): 10 km, at grade	113	11
Houston (early 1980s): 35 km, at grade	290	8

* also includes vehicle cost

Vehicle Capital Costs

		MBTA most recent order
Rail Car (Metro or LRV)	$1.5-2.5 mill	Breda $1.985 mill 100 vehicles (LRT)
Standard 40’ bus - CNG	$0.3-0.35 mill	NABI $0.31, $0.32 mill 300 vehicles
Standard 40’ trolley	$1 mill	Neoplan $0.943 mill 28 vehicles
Articulated 60’ bus - CNG	$0.5-0.7 mill	Neoplan $0.614 mill 44 vehicles
Articulated dual-mode 60’ bus		Neoplan $1.6 mill 32 vehicles

Typical Capital Costs on Per Passenger Mile Basis

Vehicle cost per passenger mile:
$0.05-0.10 for all modes

Infrastructure cost per passenger mile: $0.01-1.00

Operating Costs

In US:

- **$26.9 billion in operating costs in 2003**

By type:

- **44% for vehicle operations**
- **18% for vehicle maintenance**
- **10% for non-vehicle maintenance**
- **15% for administration**
- **13% for purchased transportation**

By mode:

- **57% for buses**
- **17% for metro**
- **12% for commuter rail**
- **3% for light rail**
- **9% for paratransit**
- **2% for other modes**

Productivity

- US transit industry has 2.5 employees per active vehicle
- Bus/rail comparison for NYCT
  (from Pushkarev and Zupan in 1970s) (employees/vehicle):

	Veh. Ops.	Veh. Maint.	Manage & Control	Fare Coll.	Way Maint.	Total
Bus	2.2	0.8	0.5	--	--	3.5
Rail	1.0	0.8	0.8	0.6	1.2	4.4

- Metro productivity is 3-4 times average bus productivity measured in pass. miles/RVH