# COST ESTIMATION

## Outline

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2. Conventional Model Types
   - Fully Allocated Causal Factor Models
   - Temporal Variation Models
   - Incremental Fixed Variable Cost Models
3. New Approaches
   - HASTUS - MACRO

# Roles For Cost Models

A. Predict cost change associated with a service change
   - -- concerned with marginal (incremental) costs
   - -- different impacts over different time periods

B. Predict cost change associated with change in production process
   - -- introduce part-time operators
   - -- contract out maintenance work

C. Subsidy allocation among jurisdictions
   - -- fairly allocate joint or overhead costs

# Classification of Transit System Expenses

## Capital Costs:

- Vehicles
- Fixed facility construction -- track, garages, stations
- Other long term physical assets

## Operating Costs:

- Labor wages and benefits
- Materials and supplies
- Other expenses incurred in operations

# National Transit Profile (2000)

| Characteristics | Bus | Heavy Rail | Commuter Rail | Light Rail | Demand Response | Total |
|---|---|---|---|---|---|---|
| Operating Expense (millions) | 12,966.1 | 3,930.8 | 2,685.3 | 606.4 | 1,804.9 | 21,993.5 |
| Capital Funding (millions) | 2,755.7 | 2,852.2 | 1,783.5 | 1,239.7 | 99.0 | 8,730.1 |
| Annual Passenger Miles (millions) | 21,241.0 | 13,843.0 | 9,402.0 | 1,355.9 | 838.4 | 46,680.3 |
| Annual Vehicle Revenue Miles (millions) | 2,001.7 | 578.2 | 247.9 | 52.1 | 645.8 | 3,525.7 |
| Annual Unlinked Trips (millions) | 5,677.7 | 2,632.2 | 412.9 | 320.1 | 104.5 | 9,147.4 |
| Average Weekday Unlinked Trips (millions) | 19.8 | 8.7 | 1.4 | 1.0 | 0.4 | 31.3 |
| Annual Vehicle Revenue Hours (millions) | 156.6 | 28.3 | 8.7 | 3.4 | 43.8 | 240.8 |
| Fixed Guideway Directional Route Miles | 1,691.0 | 1,557.7 | 5,208.7 | 834.4 | N/A | 9,291.8 |
| Vehicles Available for Maximum Service | 78,441.0 | 10,653.0 | 5,244.0 | 1,768.0 | 34,535.0 | 130,641.0 |
| Average Fleet Age in Years | 6.9 | 22.5 | 20.4 | 17.9 | 2.6 | 70.3 |
| Vehicles Operated in Maximum Service | 75,013 | 10,591 | 5,073 | 1,577 | 33,080 | 125,334 |
| Incidents | 44,312 | 14,997 | 2,338 | 1,382 | 4,609 | 67,638 |
| Fatalities | 101 | 39 | 65 | 22 | 17 | 244 |

| **Performance Measures** | | | | | |
|---|---|---|---|---|---|
| **Service Efficiency** | | | | | |
| Operating Expense/ Vehicle Revenue Mile | $6.48 | $6.80 | $10.83 | $11.64 | $2.79 |
| Operating Expense/ Vehicle Revenue Hour | $82.80 | $138.90 | $308.66 | $178.35 | $41.21 |
| **Cost Effectiveness** | | | | | |
| Operating Expense/ Passenger Mile | $0.61 | $0.28 | $0.29 | $0.45 | $2.15 |
| Operating Expense/ Unlinked Passenger Trip | $2.28 | $1.49 | $6.50 | $1.89 | $17.27 |
| **Service Effectiveness** | | | | | |
| Unlinked Passenger Trips/ Vehicle Revenue Mile | 2.8 | 4.6 | 1.7 | 6.1 | 0.2 |

# Operating Expenses (Millions of Dollars) - 2000

| Expense Type | Vehicle Operations | Vehicle Maintenance | Non- Vehicle Maintenance | General Administration | Total Expenses for 2000 |
|---|---|---|---|---|---|
| Operators' salaries and wages | 5,605.4 | 2,085.3 | 1,412.5 | 1,297.0 | 10,400.2 |
| Fringe Benefits | 3,007.9 | 966.4 | 728.1 | 710.5 | 5,412.9 |
| Services | 107.3 | 204.6 | 150.0 | 827.7 | 1,289.6 |
| Fuels & Lubricants | 563.0 | 76.5 | 2.9 | 0.0 | 642.4 |
| Materials and Supplies | 130.4 | 929.0 | 242.2 | 315.6 | 1,617.2 |
| Utilities | 123.4 | 41.8 | 358.8 | 195.8 | 719.8 |
| Casualty & Liability | 33.1 | 7.5 | 11.6 | 454.3 | 506.5 |
| Purchased Transportation | | | | | 2,761.0 |
| Other | 540.4 | -44.0 | -728.4 | -472.1 | -704.1 |
| Total Transit Agency Expenses | 10,110.9 | 4,267.1 | 2,117.7 | 3,328.8 | 22,645.5 |

*Source: National Transit Database, 2000*

# Types of Cost Models

A. Fully allocated causal factor models

B. Temporal variation models

C. Incremental fixed/variable cost models

# Fully Allocated Causal Factor Models

## Steps:

1. Select causal factors: e.g. vehicle hours, vehicle miles, and peak vehicles.

2. Assign each expense type to appropriate factor. e.g. operator wages and benefits assigned to vehicle hours, fuel assigned to vehicle miles, administration assigned to peak vehicles

3. Calculate average costs per unit of Factor *A*, *B*, and *C*:

   $$A = \frac{\text{costs assigned to vehicle hours}}{\text{total vehicle hours}}$$ etc.

4. Define cost model as:
   cost = *A* *vehicle hours + *B* *vehicle miles + *C* *peak vehicles

# Fully Allocated Approach: MBTA 1996 Cost Model: Motor Bus

| Basis of Assignment | F/V | Cost Assigned ($ Mill) | % of Total | Operating Stat. (Annual) | Unit Costs |
|---|---|---|---|---|---|
| Rev. Veh Hours | V | 79.0 | 45.5 | 2.13 million | 37.13 |
| | F | 5.7 | 3.3 | | 2.69 |
| Rev. Veh Miles | V | 50.0 | 28.8 | 22.0 million | 2.27 |
| | F | 3.0 | 1.7 | | 0.14 |
| Peak Vehicles | F | 35.9 | 20.7 | 775 | $46,323 |
| Total | | 173.6 | | | |

**Possible Cost Models:**

**Full Annual Cost =**
**(39.82 * Rev Veh Hrs + 2.41 * Rev Veh Miles) x 1.261**

**Full Annual Cost =**
**39.82 * Rev Veh Hrs + 2.41 * Rev Veh Miles + 46,323 * Peak Veh**

**Variable Annual Cost =**
**37.13 * Rev Veh Hrs + 2.27 * Rev Veh Miles**

# Temporal Variation Models

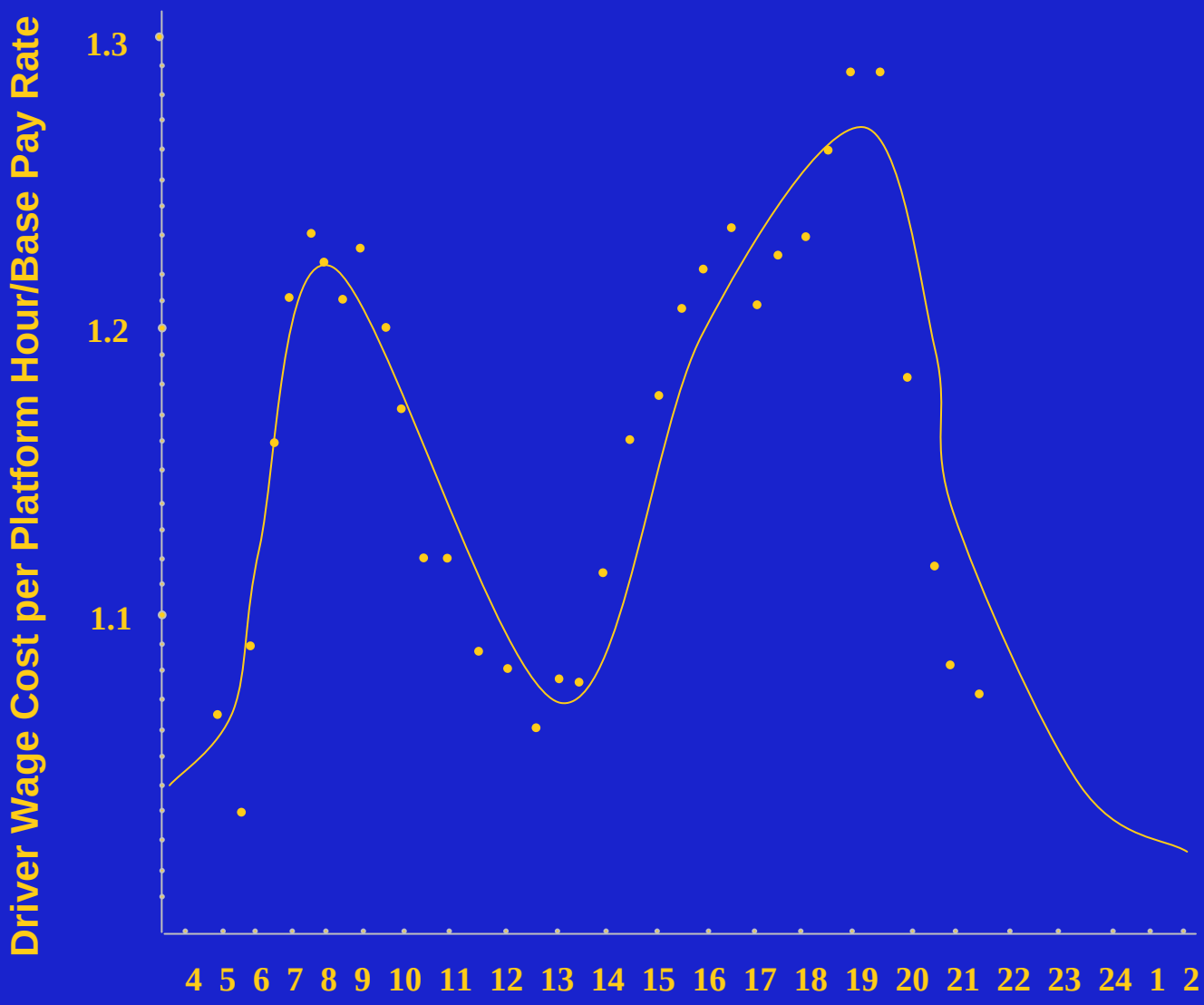
## Steps:

1. Follow fully allocated causal factor model procedure for all except operator (crew) costs.

2. To estimate operator costs, select a sample of runs, then for each 30-minute time period *t:*
   a) identify all runs, *i*, with at least 15 minutes of vehicle time in period *t*
   b) for each run *i* compute the average pay per vehicle hour by dividing daily pay $W_i$ by vehicle hours $H_i$
   c) find the minimum, average and maximum pay per vehicle hour in period *t.* Average given by:

$$W_t = \frac{\sum_{i=1}^{n} \left(\frac{W_i}{H_i}\right)}{n}$$

# Wage per Platform Hour for MBTA Drivers



# Cost Estimation Exercise

For an agency which cannot employ part-time operators, the following operator costs have been determined based on an analysis of existing operator runs:

| | Peak | Off-peak | Combined |
|---|---|---|---|
| Minimum cost/operator hour | $30 | $30 | $30 |
| Average cost/operator hour | $38 | $31 | $35 |
| Maximum cost/operator hour | $45 | $33 | $45 |

What would you estimate the incremental cost impact per operator hour to be for the following possible service changes:

a) Proportional increases in both peak and off peak services.

b) Proportional decreases in both peak and off peak services.

c) Increases in peak period services only.

d) Decreases in peak period services only.

e) Increases in off peak period services only.

f) Decreases in off peak period services only.

# Allocation of Fixed Costs Example: MBTA Bus (1996)

**Total fixed costs to be allocated (see p. 7) = $44.6 mill**

| | Weekday | | | Sat | Sun |
|---|---|---|---|---|---|
| | Base | Peak | Evening | | |
| # Buses operating | 775 | 375 | 250 | 375 | 250 |
| Hours/day | 4.5 | 6 | 4 | 12 | 12 |

A. Allocate share of fixed costs for 250 buses across all time periods:

Share of fixed costs to be allocated 250/775 = 32%

Fixed costs to be allocated = 44.6 * 0.32 = $14.4 mill

Annual bus hours operated by 250 buses

= 250(wkday hrs + Sat hrs + Sun hrs)

= 250(14.5*250 + 12*58 + 12*57)

= 1.25 mill

Average Cost/bus hour = $11.52

# Allocation of Fixed Costs Example: MBTA Bus (1996)

B. Allocate share of fixed costs for next 125 buses across all time periods except Sundays and weekday evenings

Fixed costs to be allocated = 44.6(125/775) = $7.2 mill

Annual bus hours operated by 125 buses
= 125(10.5*250 + 12*58) = 0.42 mill

Average Cost/bus hour = $17.14

C. Allocate remaining fixed costs to weekday peak service:

Fixed costs to be allocated = $23 mill

Annual bus hours operated by peak buses only
= 400*4.5*250 = 0.45 mill

Average Cost/bus hour = $51.11

D. Fixed costs will increase the variable vehicle hourly cost ($36.97) by:

$11.52 for Sunday/evening service;

$13.97 for Saturday and weekday base service;
(11.52*250/375 + 17.14*125/375)

$32.86 for weekday peak service
(11.52*250/775 + 17.14*125/775 + 51.11*400/775)

# Comparison of Traditional and Peak/Base Models: MBTA 1996 Cost Model: Motor Bus

**Traditional Model:**

**Full Annual Cost =**
**(39.82 * Rev Veh Hrs + 2.40 * Rev Veh Miles) *1.261**

**Variable Cost Model:**

**Variable Cost = 37.13 * Rev Veh Hrs + 2.27 * Rev Veh Miles**

**Peak Period Model:**

**Full Annual Peak Cost =**
**72.68 * Peak Rev Veh Hrs + 2.40 * Peak Rev Veh Miles**

**Off-Peak Period Model:**

**Full Annual Base Cost =**
**52.73 *Off-Peak Rev Veh Hrs + 2.40 *Off-Peak Rev Veh Miles**

# Incremental Fixed/ Variable Models

## Steps

1. Classify costs on the basis of variable, semi-variable, and fixed as well as the causal factors.

2. Determine unit costs for each cell of the matrix.

| | Variable | Semi-Variable | Fixed |
|---|---|---|---|
| Vehicle Hours | x | x | x |
| Vehicle Miles | x | x | x |
| Peak Vehicles | x | x | x |

3. Apply the 9 variable cost model.

# Fixed/Variable Approach Example Expense Assignment

| | Resource | | | | Cost Type | |
|---|---|---|---|---|---|---|
| Expense | Bus Hours | Bus Miles | Peak Buses | Variable | Semi-Variable | Fixed |
| Crew Wages | x | | | x | | |
| Vehicle Servicing | x | | | x | | |
| Fuel | | x | | x | | |
| Tires | | x | | x | | |
| Insurance | | x | | x | | |
| Traffic Staff | x | | | | x | |
| Miscellaneous Traffic Expenses | x | | | | x | |
| Maintenance Supervisors | x | | | | x | |
| Vehicle Maintenance | x | | | | x | |
| Workshop Expenses | x | | | | x | |
| Tickets | | | x | | x | |
| Publicity | | | x | | x | |
| Vehicle Depreciation | | | x | | x | |
| Licenses | | | x | | x | |
| Vehicle Leasing | | | x | | x | |
| Administrative Staff Costs | x | | | | | x |
| Rent | | | x | | | x |
| Building Maintenance | | | x | | | x |
| Building Utilities | | | x | | | x |
| Staff Cars | | | x | | | x |
| General Expenses | | | x | | | x |

# New Approach: HASTUS -- Macro

**Solve the Crew-Scheduling Problem in Simplified Form Using Mathematical Programming of Heuristics**

**INPUT:** Vehicle Service Requirements (Blocks) by 30-Minute (Approx.) Intervals

Driver Contract Provisions

Current Runcutting Practices

**PROCEDURE:** Solves a Linear Programming Relaxation of Run-Cutting Problem to Minimize Costs by:

- Ignoring Integrality Constraints
- Rounding Off Runs to 30 Minute Intervals
- Ignoring Spatial Issues
- Covering All Vehicle Service Hours

**OUTPUT:** Estimate a Number of Drivers by Type and Time of Run

Estimate of Total Cost