COST ESTIMATION

Outline

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2. Conventional Model Types
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   - Temporal Variation Models
   - Incremental Fixed Variable Cost Models
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   - 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 (2003)

Modes	Operating Expense (millions)	Capital Funding (millions)
Bus	12,966.1	2,755.7
Heavy Rail	3,930.8	2,852.2
Commuter Rail	2,685.3	1,783.5
Light Rail	606.4	1,239.7
Demand Response	1,804.9	99.0
Total	21,993.5	8,730.1

Operating Expenses (Millions of Dollars) - 2003

Expense Type	Vehicle Operations	Vehicle Maintenance	Non- Vehicle Maintenance	General Administration	Total Expenses for 2003
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

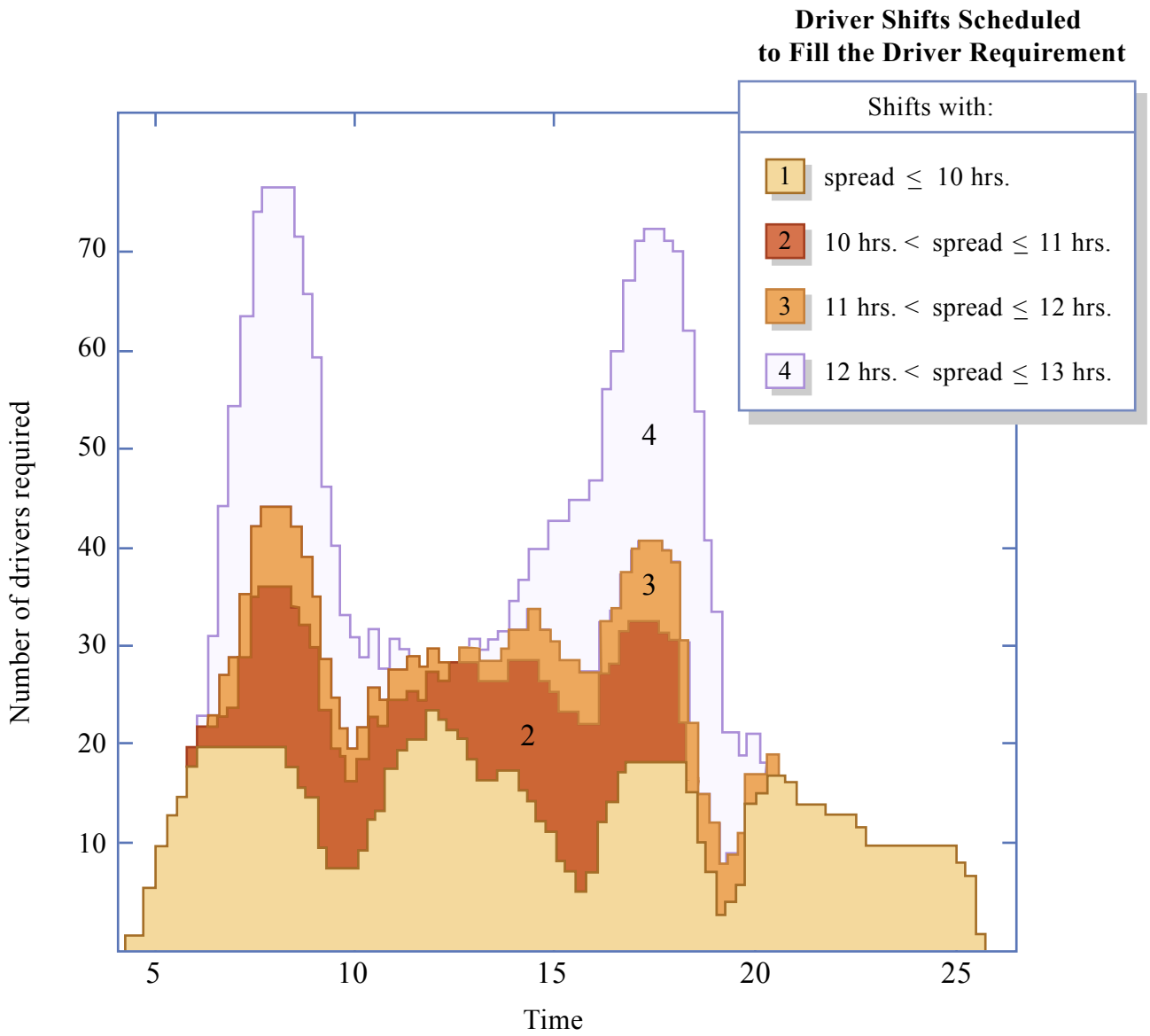
Steps:

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:

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

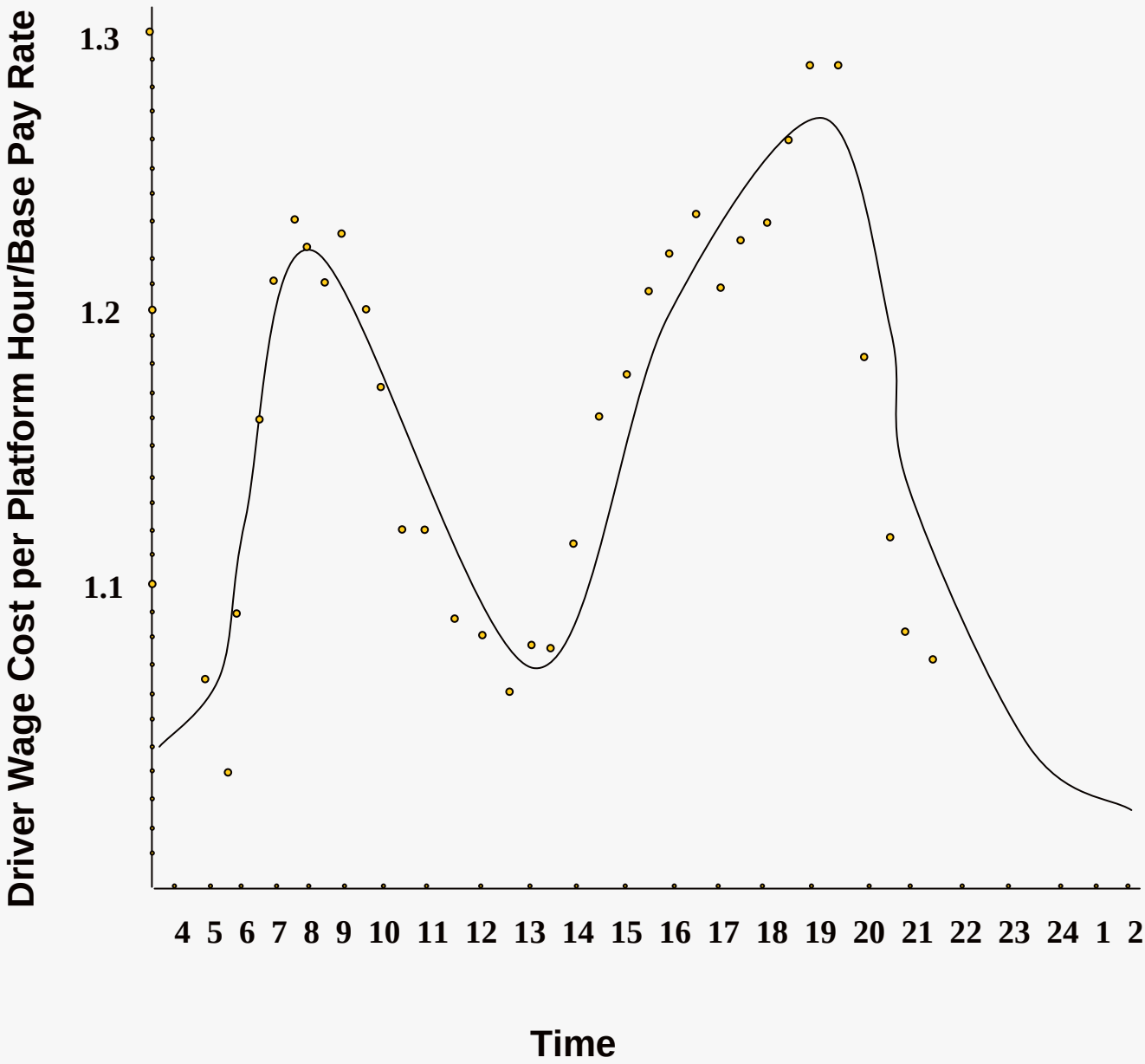
The Driver Requirement for One MBTA Garage



The figure shows the driver requirement for the Charlestown garage for the schedule period beginning June 22, 1981.

Figure by MIT OCW.

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