TRANSIT MAINTENANCE

Outline

1. Objectives of Maintenance Programs
2. Program Elements
3. Framework for Program Design
4. Maintenance Indicators
5. MBTA Experience

Objectives of Maintenance Programs

- **Safety**
  - -- paramount, must avoid unsafe operations if at all possible
  - -- key question is, are there identifiable precursors to safety failures?
- **Supply**
  - -- very common measure of maintenance effectiveness is % of scheduled pullouts met
  - -- a tension between this and reliability on the road
- **Reliability**
  - -- mean distance between failures a universal measure of maintenance effectiveness
  - -- inconsistent definitions of "failures" makes comparisons hard
- **Cost**

Program Elements

Maintenance activities can be classified as scheduled or unscheduled

A. Scheduled

A.1 Daily Servicing

-- fueling, fluid checks, minor maintenance

-- following up on operator defect reports

-- may account for 20% of total maintenance effort

-- early problem identification opportunity

-- vehicle diagnostics and computer-based monitoring of performance

Program Elements

A. Scheduled, cont'd

A.2 Inspections

- -- scheduled check on parts or systems to detect emerging problems before they result in in-service failure
- -- typical inspection program may have 2-5 inspection intervals ranging from 1,000 to 24,000 miles
- -- package each part or system into specific inspection interval to take advantage of scale economies
- -- inspections typically done in off-peak or overnight periods

Program Elements

A. Scheduled, cont'd

A.3 Preventive Parts Replacement

- -- replace certain parts before failure to avoid high failure costs
- -- integrated into an inspection cycle
- -- replacement can be based on mileage (automatic) or on condition at inspection
- -- examples are rebuilding motors or transmissions

Program Elements

B. Unscheduled: events which occur unpredictably

B.1 Repairs

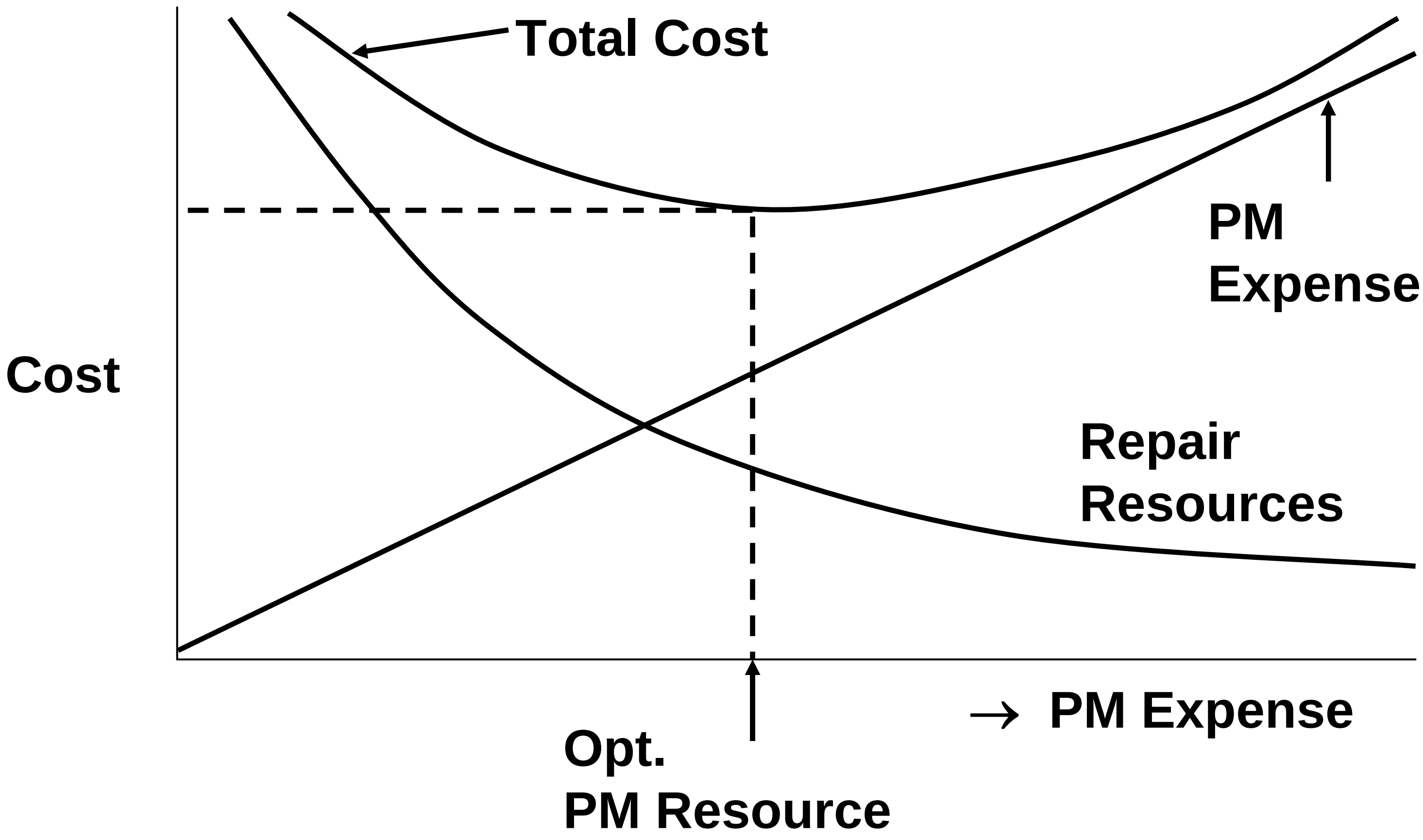
-- after a failure, typically in-service

B.2 Unscheduled Preventive Maintenance

-- replace a defective part to avoid failure

-- triggered by inspection, driver report, or diagnostic

Framework for Program Design



Analysis Framework

A. Benefits of Preventive Maintenance

- reduce probability of in-service failure
- improve system performance
- extend system life
- bring maintenance activity under management control, ease of scheduling

Analysis Framework

B. Effect of In-Service Failure

- safety risk
- effect on customers -- varies by mode
- additional mechanic cost for lower productivity work in the field, plus travel time
- surplus vehicle costs + service vehicle costs
- extra operator costs

Analysis Framework

C. Questions to address for each system/part:

- What is impact of in-service failure on:
  - -- safety
  - -- missed trips
  - -- other parts/systems
- How predictable is failure:
  - -- are there clear precursors
  - -- what is pdf for life of part/system
- What is cost of new part relative to other impacts
- What is cost of inspection

Performance Measures

Mean Distance Between Failures (MDBF)

Fleet Availability

Maintenance Cost or Productivity

MDBF

- **Vehicle Design and Technology**
  - -- Badly designed vehicle will never have a good MDBF no matter how good the maintenance
- **Operating Conditions**
  - -- MDBF is per vehicle? per train? Six car train less likely to fail than four (Why?)
  - -- What happens to MDBF in the snow?

MDBF

- **Definition**
  - -- What is a failure? What if a door is stuck, but pax could exit other doors?
  - -- MBTA: Four or more minutes' delay on the road caused by the same fault (strict)

- **Rewards Wrong Behaviour**
  - -- Maintain the train, regardless of the costs
  - -- MDBF > target == slashed budget?
  - -- No measure of residual asset value

Fleet Availability

- **Vehicle Design and Technology**
- **Operating Conditions**
- **Good Measure for Operators**
  - -- Equivalent to "bottom line", as long as the requested availability is realistic
- **Duct tape and strings?**
  - -- Vehicle that will barely limp out of the depot is still "available" for traffic
- **Spare Ratio Effects**

Maintenance Costs

- **Maintenance Unit Costs**
  - -- per Vehicle-hour? Vehicle-mile? Vehicle?
- **Maintenance Regime and Strategy Affects Costs**
  - -- Very easy to "skimp" on maintenance to produce a low cost, esp. on rail assets
  - -- Low maintenance costs can produce a low reliability
- **Cost Allocation**
  - -- Large fixed costs for depot and facilities
  - -- Renewal-enhancements seem expensive
- **Extraneous Variables**
  - -- Cost of labor, and others

Common Sense is the Answer

Transit Managers must:

- -- Understand the pitfalls of each performance measure

Performance Trends: the "Why"

Key Points to Consider

- -- MDBF, Availability
- -- Costs: Inspection or Repair
- -- Residual Asset Value
- -- Reliability/Service Level/Cost trade-off

Current US Transit Industry Maintenance Indicators

	Bus	Heavy Rail	Light Rail
MDBF (miles) (T2000)	7,000	28,000-45,000	4,000
(T 1985 winter)	5,000	1,000-4,000	1,000
Industry-wide:			
Veh Maint Employees / Vehicle Operators	0.7-0.9	1.0-1.2	1.6-1.8
Non-Veh Maint Employees / Vehicle Operators	0.1-0.3	1.8-2.2	1.1-1.7

Failure Modes (MBTA)

Failure Mode	Red 01500 01600	Red 01700	Red 01800	Green Boeing	Green Kinki
Year Built (Rebuilt)	1969 (1985)	1987	1994	1976	1986/ 1997
Air	33	9	8	23	84
Brake	7	6	17	143	143
Carbody	3	1	0	10	10
Doors	6	9	9	34	34
Electrical	5	1	2	59	59
HVAC	0	0	0	3	3
Couplers	1	0	0	6	6
Propulsion	14	16	5	89	89
Trucks	4	3	1	4	4
A.T.O.	16	10	8	0	0
Other	2	1	0	5	5
# Fleet	24+52	58	86	144	120

MBTA Maintenance Information System, Vehicle MMBF Report, Sept 2002-Mar 2003

Designing a Maintenance Regime

Maintenance economies of scope

- Shopping a car costs money, thus if a car is shopped, you should rectify all faults

Acknowledging different component life-cycles

- Silicon never dies, but motors burn up
- Decreasing rate of failure components: air valves you leave alone once you install

Designing a Maintenance Regime

Determining the optimal # spares

- Incremental benefit of marginal train versus marginal benefit of more reliable fleet or cheaper maintenance practices

Target the problem car or the problem subsystem (MBTA)

- Incremental increases in time between inspections might be possible

Applying Formal Maintenance Theory

Theory works better when

- Consequences of failure is less severe and easily evaluated
- Component life cycles are well known
- Costs of in-service repair are well defined

Current MBTA regime is

- Block replacement of most consumables

Applying Formal Maintenance Theory

MBTA is improving by

- Developing a better maintenance information system

MBTA could improve by

- More aggressively keep track of component life cycles, permitting some to be replaced every other inspections
- Reexamine coverage ratios requested, with integrated maintenance/operations cost-benefit analysis