TRANSIT MAINTENANCE

Outline

1. Objectives of Maintenance Programs
2. Program Elements
3. Framework for Program Design
4. Maintenance Indicators
5. Parts of a Railcar
6. 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

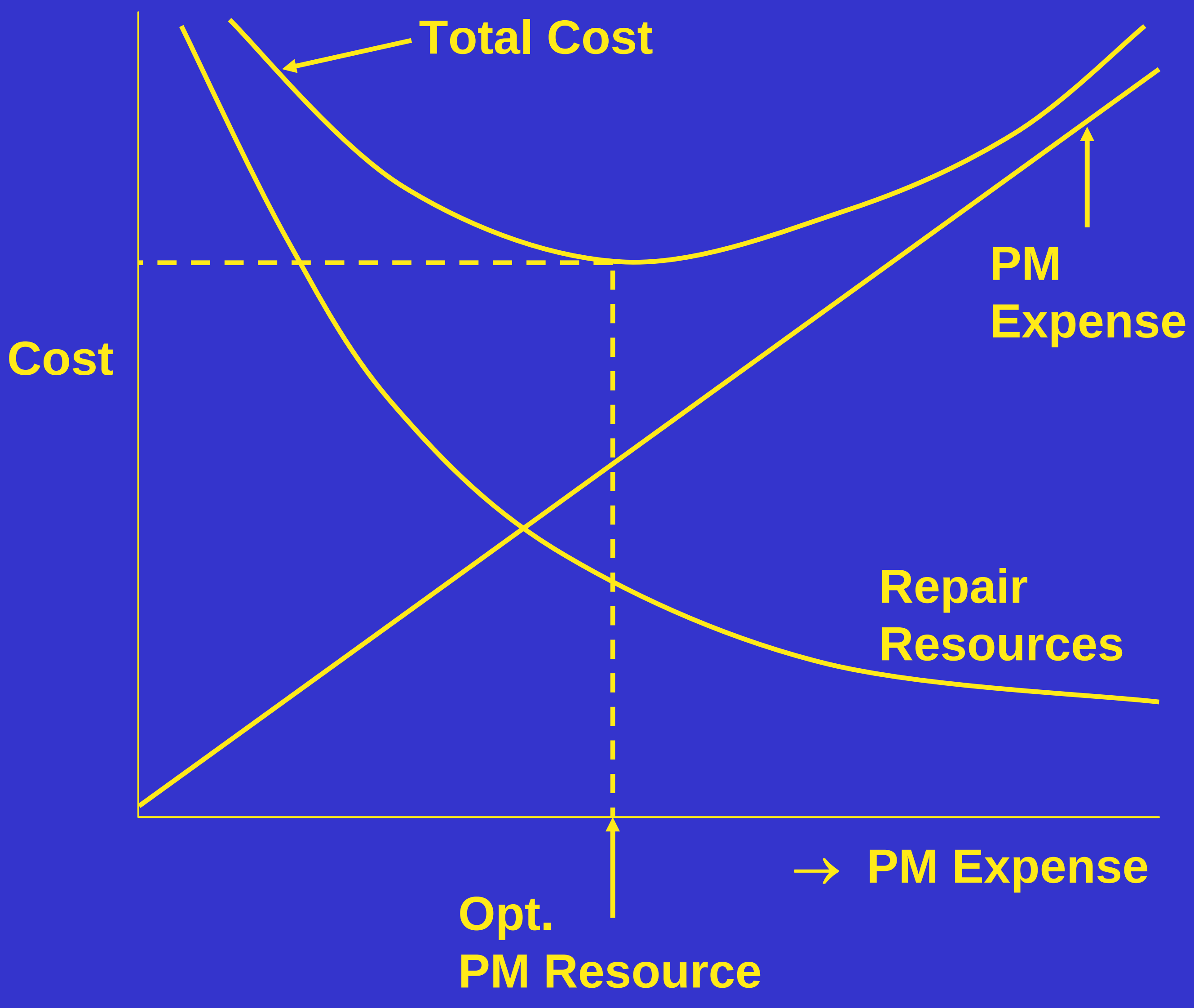
B.1 Repairs

- -- 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?
- 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

Typical Spare Ratio 10-20%

Railcar Bingo

Courtesy of Todd Glickman. Used with permission.

Trucks	Rheostats	Traction Motors
Anti-climbers	Compressor	Shoes
Drive Packages	Battery	Couplers
Yaw-dampers	Solebar	A.T.O.

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, September 2002-March 2003

Failure Mode Issues

- "Train Dumps" – air system, brake system, or A.T.O.?
- Propulsion – motor flashover, software glitch, or electronics?
- Tracking failure modes accurately very important
  - Dispatcher report would not suffice
  - Best if depot keep track of repairs and costs incurred

Railcar Technologies

- "Hawker-Siddeley's rust out"?
- "01800's have lousy brakes"?
- "Green Line has low MDBF"?
- Can't compare across fleets!
  Apples (Red) and Oranges!

Technologies	Red 01500 01600	Red 01700	Red 01800	Green Boeing	Green Kinki	Orange OROO
Traction	D.C.	D.C.	A.C.	D.C.	D.C	D.C
Brakes	Rheo.	Rheo.	Regen.	Mag.	Regen + Mag.	Rheo.
Carbody	Alum.	Alum.	S.S.	Steel	Steel	Steel
Current Collect.	Shoes	Shoes	Shoes	Panto.	Panto.	Shoes
Control	C.R.	C.R.	G.T.O.	?	Chopper	C.R.

S.S. = Stainless Steel
C.R. = Camshaft Resistance
G.T.O. = Gate Turn-off Thrystor Chopper

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
- **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
- 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

Resources on Railcar Maintenance

Little, P. ***Improving Railroad Freight Car Reliability Using a New Opportunistic Maintenance Heuristic*****. MIT Thesis (1991).**

Haven, P. ***Transit Vehicle Maintenance: Framework for Development of More Productive Programs*****. MIT Thesis (1980).**

Barry, A. ***Managing Improvements of a Well-Run Transit Rail Vehicle Maintenance Operations*****. TRB Preprint Series No. 961293 (1996).**

Hall, R. ***Scheduling Transit Railcar Maintenance and Facility Design*****. Transportation Research (2000).**

http://www.trainweb.org/railwaytechnical/train-maint.html

http://www.trainweb.org/railwaytechnical/Manufacture.html

http://www.trainweb.org/railwaytechnical/drives.html

Appendix: Why are Trains Broken?

- Conductive dust – flashovers
- Wrong kind of snow
- Vibration shakes stuff loose
- Condensation in air system
- Overheat – outside design spec.
- Mechanical wear and tear
  - Motor brushes… Brake blocks…
  - Door motors… Rollsigns…
- Vandalism: windows and interior
- Wheel wear, wheel out of round
- Electrical: shorts, wiring degradation
- Corrosion – accumulated damp
- … and the occasional hard couple