WORKFORCE PLANNING

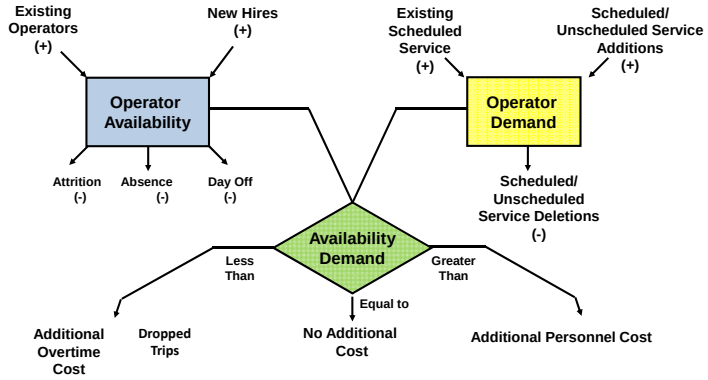
Outline

1. Problem description
2. General Approach
3. Strategic Level Model and Case Study
4. Tactical Level Model and Case Study
5. Operational Level Model and Case Study

Challenge

- Provide the best, most reliable service at the least cost
- Scheduled service requires certain level of manpower
- When manpower is not available:
  - Overtime
    - Absenteeism
  - Dropped trips
  - Service reliability
  - Customer satisfaction
- Workforce planning as solution

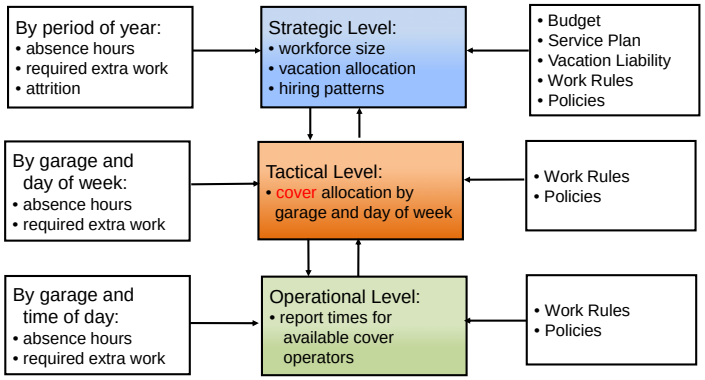
Basic Variables in Workforce Planning



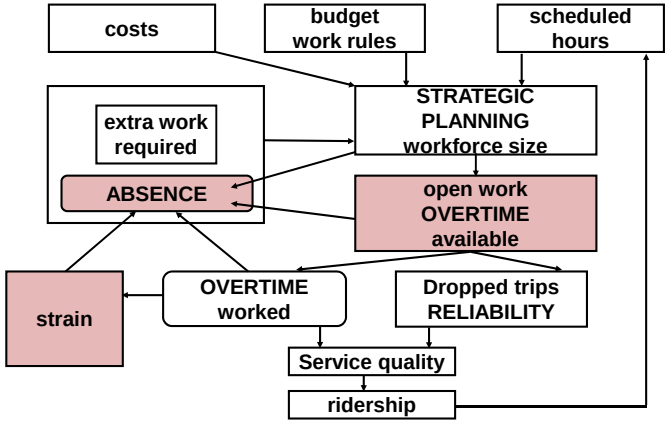
Three Levels of Planning

- **Strategic**
  - Rightsizing workforce
    - Timetable requirements
    - Vacation allocation
    - Hiring Plan
  - Personnel policies - "True" part-timers
- **Tactical**
  - Staffing by garage and by day of week
- **Operational**
  - Daily report times for unassigned extra staff

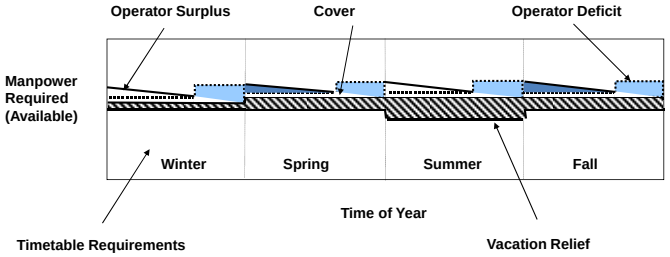
Planning Activities at Each Level



Planning Variables

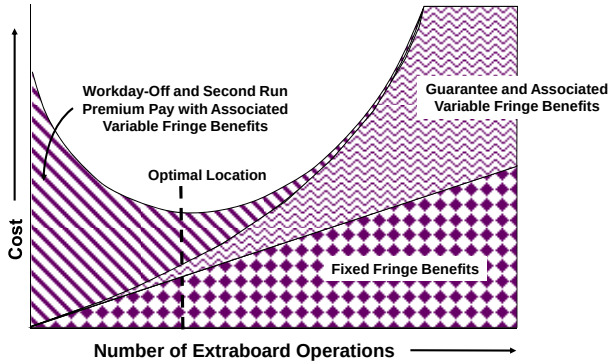


Need for Monthly Hiring

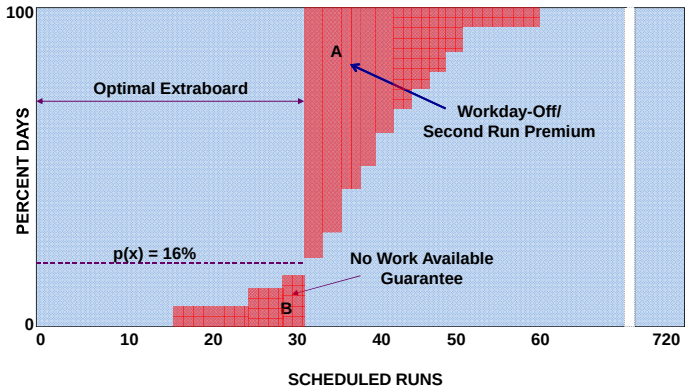


Results:
- Unassigned cover time at start of timetable
- Large amounts of overtime at end of timetable
- Poor reliability at end of timetable

Total Cost



Optimal Extraboard Size and Unscheduled Guarantee and Premium



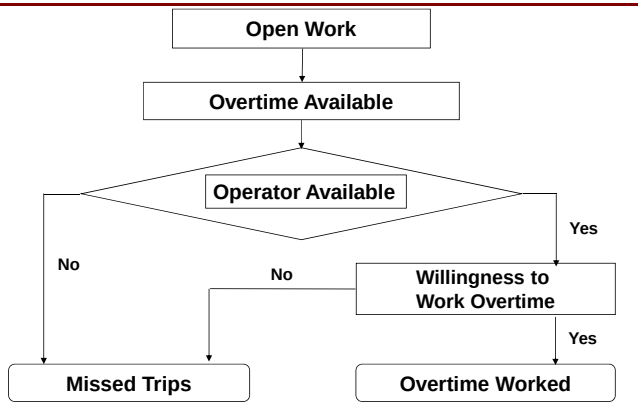
The Strategic Level Approach

1. Decision Variables
   - Workforce Size for Each Period
   - Vacation Allocation for Each Period
   - Optimal Hiring Levels for Each Period
2. Objective: Minimize Workforce Cost
   - Scheduled Runs
   - Extraboard
   - Overtime

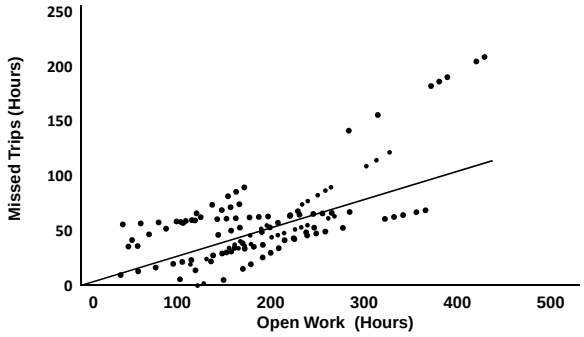
The Strategic Level Approach

3. Constraints
   - Vacation Liability
   - Overtime
   - Service Reliability
   - Part-time Operation Constraints
   - Other Policy Constraints

A Reliability Model



Missed Service Hours



Missed Service Hours = 0.28 x Open Work Hours

Case Study

(Based on Massachusetts Bay Transportation Authority Bus Operations)

Characteristics

- Part-time workforce sized to 40% of the full-time workforce
- Large variability in the required work hours
- Mean Daily Absence and Extra Work:
  - 1250 hours
- Daily Standard Deviation of Absence and Extra Work:
  - 290 Hours

MBTA Cost Analysis (1996)

	Overtime	Part-Timer	Full-Timer
Wage Rate ($/Hour)	29.04	19.36	19.36
Full Cost/Hour Worked	32.72	31.24	34.78
Marginal Cost if last extraboard used 75% of time	--	41.65	46.37
Marginal Cost if last extraboard used 50% of time	--	62.48	69.56

Results of Constant Hiring and Constant Vacation Constraints

	Base Case	Constant Hiring	Constant Vacation	Constant Hiring & Vacation
FT Oper	1,257	1,257	1,291	1,316
PT Oper	654	654	666	685
Overtime (%)	1.5	1.5	0.9	0.3
OT cost*	1.5	1.5	0.9	0.3
Reg cost*	96.4	96.4	98.8	100.9
Tot cost*	97.8	97.8	99.7	101.2
Reliability (%)	99.6	99.6	99.8	99.9

Results for Different Overtime Constraints

	Base Case 1.5% OT	no OT Const	5% OT Const	1% OT Const
FT Oper	1,266	1,104	1,202	1,267
PT Oper	654	575	625	660
Overtime (%)	1.5	12.2	5.0	1.0
OT cost*	1.4	11.8	4.8	1.0
reg cost*	96.4	84.7	92.2	97.2
tot cost*	97.8	96.5	97.0	98.2
reliability (%)	99.6	97.0	98.8	99.8

*** Costs are in millions of dollars per year**

Tactical Level (Day of Week/Garage)

Objective: minimize weighted sum of
- overtime
- missed trips

Decision variables: allocate extra staff
- by garage (area of depot)
- by day of week

Inputs:
- operator timetable requirements by day of week and garage
- mean and standard deviation of absence and required extra work by day of week and garage

Tactical Level (Day of Week/Garage)

Constraints: total available operators

Key relationships:
- requested overtime as a function of total available operators, timetable requirements, absence, and required extra work
- missed service as a function of requested overtime

Method: heuristic or optimization method

Application of Tactical Model to Single MBTA Garage

	Open Work (hours)		Extraboard Allocation (days)			Exp. Overtime (hours)	
	Mean	Std. dev.	Actual FTOs	Recomm. FTOs	PTOs	Actual	Recomm.
Monday	259	36	20	21	13	17	11
Tuesday	200	31	20	14	13	0	12
Wednesday	212	36	20	16	13	2	15
Thursday	233	30	20	18	13	7	14
Friday	278	52	20	24	13	38	21
Saturday	185	24	17	22	0	50	15
Sunday	84	25	7	10	0	26	11
	TOTAL		124	125		140	99

Tactical Level Findings

- Significant variation in absence and required extra work
  - by garage
  - by day of week
- Variably sized extraboard is appropriate
  - by garage
  - by day of week
- Data required on absence and extraboard utilization by garage and day of week

Operational Level (Daily Level)

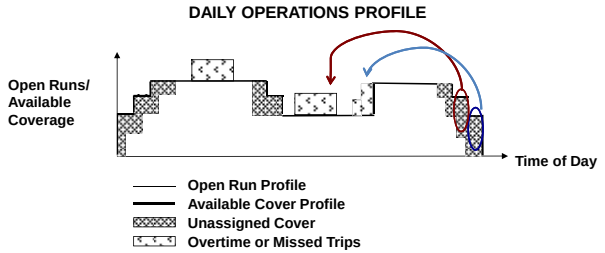
Objective: minimize weighted sum of
- overtime
- missed trips

Decision variables: extra staff report times in ranked order
- by garage (area or depot)
- by day of week

Inputs:
- operator timetable requirements by time of day
- known extra work by time of day

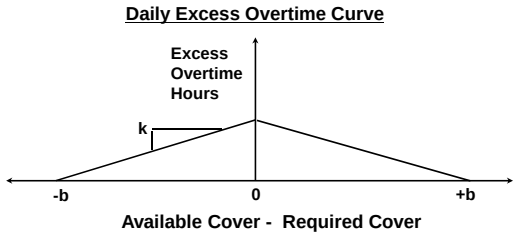
Overtime and Feedback

1. Regular Overtime
   - the result of more required work than available extraboard on a given day
2. Excess Overtime
   - the result of inherent inefficiency in assigning daily report times



The Excess Overtime Curve

- Excess overtime is a maximum when the number of required work hours exactly matches the number of extraboard hours available
- Excess overtime decreases with fewer required work hours or available workforce hours



Operational Level (Daily Level)

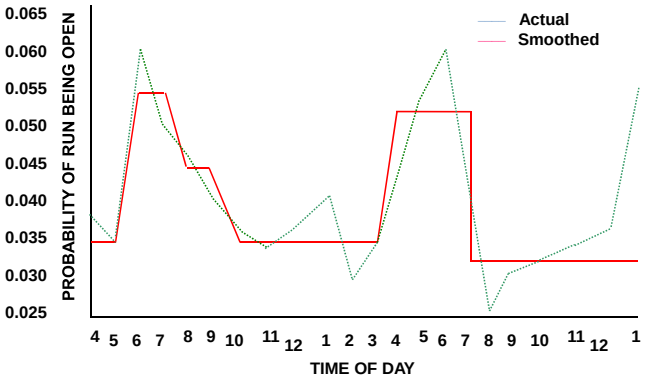
Constraints: extraboard work rules

Key relationships:

- likelihood of missed trip resulting if no cover operator available, by time of day

Method: heuristic or optimization method

Probability of Open Run Profile



Unexpected Absences by Day-of-Week

Unexpected Absence Hours					Known Absence Hours	Scheduled Hours	Avg. Prob. of Open Runs
	Max	Min	Mean	Std. Dev.			
Sat	98.0	30.5	68.7	18.8	112.0	2044	0.034
Sun	48.0	0.0	23.6	12.8	59.6	815	0.029
Mon	130.0	51.5	93.7	23.9	163.7	2282	0.041
Tue	78.5	39.0	62.6	12.3	135.3	2282	0.027
Wed	77.0	22.5	54.1	21.2	157.3	2282	0.024
Thu	115.5	46.5	75.4	20.4	155.3	2282	0.033
Fri	140.5	55.5	88.4	28.0	188.9	2282	0.039
Avg. Weekday			74.8		160.1	2282	0.033

Expected Weighted Uncovered Open Work

Day of Week	DHS	HS	FLAT
Monday	53.34	54.96	53.12
Tuesday	19.36	19.18	19.42
Wednesday	41.42	41.31	41.89

Assumes 6 FTOs, 4 PTOs available on extraboard

Key: DHS = day and hour specific absence rates
HS = assumes hour specific absence rates only
FLAT = assumes constant absence rate for all days and hours

Evaluating Current Practice: Weighted Uncovered Open Work (Hours)

Date	Rep. Oper. (FTO-PTO)	Actual Open Hours	Model Results
6/29	11-7	36.1	26.9
7/06	3-0	118.1	112.3
7/13	6-6	64.0	54.3
7/20	8-12	40.1	22.0
7/27	10-5	53.0	36.6

Data are for 5 consecutive Mondays for a specific MBTA garage

Actual vs. Recommended Report Times

Monday, 7/13		Monday, 7/27	
Actual	Recommended	Actual	Recommended
	4.45	4.30	4.30
5.00	5.00	4.30	
	5.30		4.45
	5.45	5.00	5.00
6.00	6.00	5.00	
6.00	6.00	5.00	
	6.00	5.30	5.30
7.00			5.45
7.00		6.00	6.00
7.00		6.00	6.00
7.00		6.00	6.00
8.00		6.00	
8.00		6.00	
	13.45		6.15
	14.00	6.30	
	14.00	8.00	
	14.15	12.00	
	15.30	13.00	
15.45			13.45
18.15			14.00
20.00			14.00
			14.15
			14.45
			16.00

Operational Level Findings

- Significant improvements possible
  - reduced overtime
  - reduced missed trips
- Single set of ranked report times can be used across all weekdays and seasons for each garage
  - separate ranked report times required for Saturdays, Sundays
- Constant absence rates can be assumed
  - by hour of day
  - by day of week

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