WORKFORCE PLANNING

Outline

1. Problem description
2. General Approach
3. Strategic Level Case Study
4. Tactical Level Case Study
5. Operational Level Case Study
Basic Variables Affecting Manpower Level Decisions

operator availability

attrition

absence

day off

new hires

existing operators

existing scheduled service

demand

scheduled/unscheduled service additions

service deletions

availability demand

less than

additional overtime cost

less benefit cost

no additional cost

greater than

equal to

additional guarantee cost

additional benefit cost
General Approach

Strategic Level
- workforce size
- hiring plan
- vacation allocation

Tactical Level
- extra staff by day of week

Operational Level
- report times for unassigned extra staff
Problem Description

By period of year:
• absence hours
• required extra work
• attrition

Strategic Level:
• workforce size
• vacation allocation
• hiring patterns

• Budget
• Service Plan
• Vacation Liability
• Work Rules
• Policies

Tactical Level:
• extraboard allocation by garage and
day of week

• Work Rules
• Policies

Operational Level:
• report times for available extraboard
operators

• Work Rules
• Policies

By garage and day of week:
• absence hours
• required extra work

By garage and time of day:
• absence hours
• required extra work
Lecture 19-20

- Costs
- Scheduled work
- Work rules
- Workforce size
- Strategic planning

ABSENCE
- Extra work required

OVERTIME
- Worked
- Available
- Missed trips
- Reliability

STRAIN
- Missed trips

L.o.s.
- Ridership

Nigel H.M. Wilson
1.259J/11.542J/ESD/227J, Fall 2006
Lecture 19-20
A. Quarterly Hiring

Implications:
- Unassigned cover time at start of timetable
- Large amounts of overtime at end of timetable
- Poor reliability at end of timetable
Total Unscheduled Pay

Cost

Number of Extraboard Operations

- Workday-Off and Second Run Premium Pay with Associated Variable Fringe Benefits
- Guarantee and Associated Variable Fringe Benefits
- Fixed Fringe Benefits

Optimal Location
Optimal Extraboard Size and Unscheduled Guarantee and Premium

\[ p(x) = 16\% \]

Optimal Extraboard

Workday-Off/Second Run Premium

No Work Available Guarantee

\[ p(x) = 16\% \]
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
3. Constraints

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

[Diagram: DAILY OPERATIONS PROFILE]

- Open Run Profile
- Available Cover Profile
- Unassigned Cover
- Overtime or Missed Trips

Time of Day

Open Runs/Available Coverage
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.

Daily Excess Overtime Curve

Excess Overtime Hours

Available Cover - Required Cover

\[ -b \quad 0 \quad +b \]
Expected Overtime for the Period

• Takes into account of variation of both the required work hours and day-to-day variability of the size of the extraboard

![Graph of Regular and Excess Overtime](image)

**WORKFORCE - AVERAGE REQUIRED WORK**
Overtime Effects on Total Workforce Costs

TOTAL WORKFORCE COSTS

TOTAL COST

SCHEDULED WORKFORCE

TOTAL OT

REGULAR OT

EXCESS OT

COSTS

WORKFORCE - AVERAGE REQUIRED WORK

TOTAL WORKFORCE - AVERAGE REQUIRED WORK
A Reliability Model

Open Work

Overtime Available

Operator Available

Missed Trips

Willingness to Work Overtime

Overtime Worked
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)

<table>
<thead>
<tr>
<th></th>
<th>Overtime</th>
<th>Part-Timer</th>
<th>Full-Timer</th>
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<tbody>
<tr>
<td>Wage Rate ($/Hour)</td>
<td>29.04</td>
<td>19.36</td>
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<td>Full Cost/Hour Worked</td>
<td>32.72</td>
<td>31.24</td>
<td>34.78</td>
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<td>Marginal Cost if last extraboard used 75% of time</td>
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<td>41.65</td>
<td>46.37</td>
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<tr>
<td>Marginal Cost if last extraboard used 50% of time</td>
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<td>62.48</td>
<td>69.56</td>
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Available Operator Hours

O = regular time cost
○ = regular time cost + regular OT cost
x = total cost
## Results of Constant Hiring and Constant Vacation Constraints

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Constant Hiring</th>
<th>Constant Vacation</th>
<th>Constant Hiring &amp; Vacation</th>
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<tr>
<td><strong>FT Oper</strong></td>
<td>1256.50</td>
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<td>1290.60</td>
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<td><strong>PT Oper</strong></td>
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<td>653.90</td>
<td>665.70</td>
<td>684.80</td>
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<td><strong>Overtime (%)</strong></td>
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<td>1.50</td>
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<td><strong>OT cost</strong>*</td>
<td>1.45</td>
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<td>0.88</td>
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<tr>
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<td>98.78</td>
<td>100.93</td>
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<tr>
<td><strong>Tot cost</strong>*</td>
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<td>99.65</td>
<td>101.23</td>
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<tr>
<td><strong>Reliability (%)</strong></td>
<td>99.60</td>
<td>99.60</td>
<td>99.80</td>
<td>99.90</td>
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</table>
## Results for Different Overtime Constraints

<table>
<thead>
<tr>
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<th>Base Case 1.5% OT</th>
<th>no OT Const</th>
<th>5% OT Const</th>
<th>1% OT Const</th>
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</thead>
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<td>1104</td>
<td>1202</td>
<td>1267</td>
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<tr>
<td>PT Oper</td>
<td>654</td>
<td>575</td>
<td>625</td>
<td>660</td>
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<td>Overtime (%)</td>
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<td>1.0</td>
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<td>OT cost*</td>
<td>1.4</td>
<td>11.8</td>
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<td>1.0</td>
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<td>96.4</td>
<td>84.7</td>
<td>92.2</td>
<td>97.2</td>
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<tr>
<td>tot cost*</td>
<td>97.8</td>
<td>96.5</td>
<td>97.0</td>
<td>98.2</td>
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<tr>
<td>reliability (%)</td>
<td>99.6</td>
<td>97.0</td>
<td>98.8</td>
<td>99.8</td>
</tr>
</tbody>
</table>

*Costs are in millions of dollars per year*
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
(Timetable/Rating Level)

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

<table>
<thead>
<tr>
<th></th>
<th>Open Work (hours)</th>
<th>Extraboard Allocation (days)</th>
<th>Exp. Overtime (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. dev.</td>
<td>Actual FTOs</td>
</tr>
<tr>
<td>Monday</td>
<td>259</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Tuesday</td>
<td>200</td>
<td>31</td>
<td>20</td>
</tr>
<tr>
<td>Wednesday</td>
<td>212</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Thursday</td>
<td>233</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Friday</td>
<td>278</td>
<td>52</td>
<td>20</td>
</tr>
<tr>
<td>Saturday</td>
<td>185</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>Sunday</td>
<td>84</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
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

PROBABILITY OF RUN BEING OPEN

TIME OF DAY

Actual

Smoothed

0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
# Unexpected Absences by Day-of-Week

<table>
<thead>
<tr>
<th>Unexpected Absence Hours</th>
<th>Known Absence Hours</th>
<th>Scheduled Hours</th>
<th>Avg. Prob. of Open Runs</th>
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</thead>
<tbody>
<tr>
<td>Max</td>
<td>Min</td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Sat</td>
<td>98.0</td>
<td>30.5</td>
<td>68.7</td>
</tr>
<tr>
<td>Sun</td>
<td>48.0</td>
<td>0.0</td>
<td>23.6</td>
</tr>
<tr>
<td>Mon</td>
<td>130.0</td>
<td>51.5</td>
<td>93.7</td>
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<tr>
<td>Tue</td>
<td>78.5</td>
<td>39.0</td>
<td>62.6</td>
</tr>
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<td>Wed</td>
<td>77.0</td>
<td>22.5</td>
<td>54.1</td>
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<td>Thu</td>
<td>115.5</td>
<td>46.5</td>
<td>75.4</td>
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<td>Fri</td>
<td>140.5</td>
<td>55.5</td>
<td>88.4</td>
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<tr>
<td>Avg. Weekday</td>
<td>74.8</td>
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</table>
# Expected Weighted Uncovered Open Work

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>DHS</th>
<th>HS</th>
<th>FLAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>53.34</td>
<td>54.96</td>
<td>53.12</td>
</tr>
<tr>
<td>Tuesday</td>
<td>19.36</td>
<td>19.18</td>
<td>19.42</td>
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<tr>
<td>Wednesday</td>
<td>41.42</td>
<td>41.31</td>
<td>41.89</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Date</th>
<th>Rep. Oper. (FTO-PTO)</th>
<th>Actual Rep.</th>
<th>Model Results</th>
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<tbody>
<tr>
<td>6/29</td>
<td>11-7</td>
<td>36.1</td>
<td>26.9</td>
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<td>7/06</td>
<td>3-0</td>
<td>118.1</td>
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<td>6-6</td>
<td>64.0</td>
<td>54.3</td>
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<tr>
<td>7/20</td>
<td>8-12</td>
<td>40.1</td>
<td>22.0</td>
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<tr>
<td>7/27</td>
<td>10-5</td>
<td>53.0</td>
<td>36.6</td>
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</table>

Data are for 5 consecutive Mondays for a specific MBTA garage
### Actual vs. Recommended Report Times

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday, 7/13 Actual</th>
<th>Monday, 7/13 Recommended</th>
<th>Monday, 7/27 Actual</th>
<th>Monday, 7/27 Recommended</th>
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<tbody>
<tr>
<td>5.00</td>
<td>4.45</td>
<td>5.00</td>
<td>4.30</td>
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</table>
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