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
  - Absentees
  - 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

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

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

Tactical Level:
- cover allocation by garage and day of week
- work rules
- policies

By garage and time of day:
- absence hours
- required extra work

Operational Level:
- report times for available cover operators
- work rules
- policies

Planning Variables

- costs
- budget work rules
- scheduled hours

strains
- extra work required
- absence
- overtime worked
- open work
- overtime available
- dropped trips
- reliability
- service quality
- ridership

Total Cost

- workday-off and second run
- premium pay with associated variable fringe benefits
- guarantee and associated variable fringe benefits
- fixed fringe benefits
- optimal location
- number of extraboard operations

Need for Monthly Hiring

- manpower required (available)
- cover
- operator surplus
- operator deficit

Winter
Spring
Summer
Fall

Timetable requirements

Results:
- unassigned cover time at start of timetable
- large amounts of overtime at end of timetable
- poor reliability at end of timetable
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

A Reliability Model

- Open Work
  - Overtime Available
    - Operator Available
      - Yes
      - No
    - No
      - Willingness to Work Overtime
        - Yes
        - No
      - Missed Trips
    - Overtime Worked
      - Yes
      - No
Missed Service Hours

Missed Trips (Hours)

0 50 100 150 200 250

Open Work (Hours)

0 100 200 300 400 500

Missed Service Hours = 0.28 x Open Work Hours

MBTA Cost Analysis (1996)

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

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

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>
</tr>
</thead>
<tbody>
<tr>
<td>FT Oper</td>
<td>1,257</td>
<td>1,257</td>
<td>1,291</td>
<td>1,316</td>
</tr>
<tr>
<td>PT Oper</td>
<td>654</td>
<td>654</td>
<td>666</td>
<td>685</td>
</tr>
<tr>
<td>Overtime (%)</td>
<td>1.5</td>
<td>1.5</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>OT cost*</td>
<td>1.5</td>
<td>1.5</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Reg cost*</td>
<td>96.4</td>
<td>96.4</td>
<td>98.8</td>
<td>100.9</td>
</tr>
<tr>
<td>Tot cost*</td>
<td>97.8</td>
<td>97.8</td>
<td>99.7</td>
<td>101.2</td>
</tr>
<tr>
<td>Reliability (%)</td>
<td>99.6</td>
<td>99.6</td>
<td>99.8</td>
<td>99.9</td>
</tr>
</tbody>
</table>
### Results for Different Overtime Constraints

<table>
<thead>
<tr>
<th>Base Case</th>
<th>1.5% OT</th>
<th>no OT Const</th>
<th>5% OT Const</th>
<th>1% OT Const</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT Oper</td>
<td>1.266</td>
<td>1.104</td>
<td>1.202</td>
<td>1.267</td>
</tr>
<tr>
<td>PT Oper</td>
<td>654</td>
<td>575</td>
<td>625</td>
<td>660</td>
</tr>
<tr>
<td>Overtime (%)</td>
<td>1.5</td>
<td>12.2</td>
<td>5.0</td>
<td>1.0</td>
</tr>
<tr>
<td>OT cost*</td>
<td>1.4</td>
<td>11.2</td>
<td>5.0</td>
<td>1.0</td>
</tr>
<tr>
<td>reg cost*</td>
<td>96.4</td>
<td>84.7</td>
<td>92.2</td>
<td>97.2</td>
</tr>
<tr>
<td>tot cost*</td>
<td>97.8</td>
<td>96.5</td>
<td>97.0</td>
<td>98.2</td>
</tr>
<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.

### 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

<table>
<thead>
<tr>
<th>Open Work (hours)</th>
<th>Extraboard Allocation (days)</th>
<th>Exp. Overtime (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Std. dev.</td>
<td>Actual FTOs</td>
</tr>
<tr>
<td>Monday</td>
<td>259</td>
<td>36</td>
</tr>
<tr>
<td>Tuesday</td>
<td>203</td>
<td>31</td>
</tr>
<tr>
<td>Wednesday</td>
<td>212</td>
<td>36</td>
</tr>
<tr>
<td>Thursday</td>
<td>233</td>
<td>30</td>
</tr>
<tr>
<td>Friday</td>
<td>278</td>
<td>52</td>
</tr>
<tr>
<td>Saturday</td>
<td>185</td>
<td>24</td>
</tr>
<tr>
<td>Sunday</td>
<td>84</td>
<td>25</td>
</tr>
<tr>
<td>TOTAL</td>
<td>124</td>
<td>125</td>
</tr>
</tbody>
</table>

**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 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

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Unexpected Absences by Day-of-Week

<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>
</tr>
<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

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Probability of Open Run Profile

Expected Weighted Uncovered Open Work
Evaluating Current Practice: Weighted Uncovered Open Work (Hours)

<table>
<thead>
<tr>
<th>Date</th>
<th>Rep. Oper. (FTO-PTO)</th>
<th>Actual Open Hours</th>
<th>Model Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/29</td>
<td>11-7</td>
<td>36.1</td>
<td>26.9</td>
</tr>
<tr>
<td>7/06</td>
<td>3-0</td>
<td>118.1</td>
<td>112.3</td>
</tr>
<tr>
<td>7/13</td>
<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>
</tr>
</tbody>
</table>

Data are for 5 consecutive Mondays for a specific MBTA garage

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

Actual vs. Recommended Report Times

<table>
<thead>
<tr>
<th>Monday, 7/13</th>
<th>Monday, 7/27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td>Recommended</td>
</tr>
<tr>
<td>5:00</td>
<td>4:45</td>
</tr>
<tr>
<td>6:00</td>
<td>5:00</td>
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<tr>
<td>7:00</td>
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<tr>
<td>20:00</td>
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</tbody>
</table>