Optimizing the service of the Orange Line
Overview

- Increased crime rate in and around campus
- Shuttle-UM Orange Line
- 12:00am – 3:00am late night shift
- A student standing or walking on and around campus during these hours has a greater chance of being susceptible to crime
Objective

- Increase Frequency of Service = Decrease avg. waiting time
- Remain Cost Effective
- Possible Improvements:
  - Larger shuttles
  - Increase fleet size
  - Reduce # of stops
Course Concepts

- For this project we used linear programming formulation to determine a best solution given our approaches.

- Each approach has an objective function, decision variables, constraints, and parameters. Non-negativity of variables was assumed for each approach because a negative number of vehicles or stops would not be applicable in this project.

- The ‘gin’ command was used to determine general integer variables because fractions cannot be applied to number of vehicles or stops.
Current Orange Line Schedule

1 Shuttle running on Sunday-Wednesday late night shift

3 Shuttles running on Thursday-Saturday shift

Shaded vs. Un-shaded
Orange Line Information

- Round Trip Distance: 4.66mi
- Round Trip Time (R): 30min
- Seat Capacity (s): 36
- Total Capacity: 69 passengers
- Mean dwell time: 45sec (5sec-5min)
  - Sun-Wed: 21 secs
  - Thurs-Sat: 78 secs
- Frequency Sun-Wed: 2 shuttles/hr
- Frequency Thurs-Sat: 6 shuttles/hr
- Operating Cost per bus (C): $50/hr
  - Driver: $12.85
  - Maintenance (tires, oil, filter, etc.): $3.20
  - Fuel: $6.50
  - Depreciation: $13.45
  - Overhead (plant, administrative salaries, storage): $14.00
Alternative #1

(+) Larger seating and load capacity needed @ peak hours

(-) Frequency remains unchanged

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<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>Current</th>
<th>Using Larger Shuttle (Th-Sat)</th>
<th>Additional Operating Cost /Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>$12.85</td>
<td>$12.85</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>$3.20</td>
<td>$4.26</td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>$6.50</td>
<td>$8.65</td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>$13.45</td>
<td>$17.89</td>
<td></td>
</tr>
<tr>
<td>Overhead</td>
<td>$14.00</td>
<td>$16.50</td>
<td></td>
</tr>
<tr>
<td>Cost/Semester</td>
<td>$17,850.00</td>
<td>$19,402.95</td>
<td>$1,552.95</td>
</tr>
</tbody>
</table>

(-) Additional $1,552.95/semester
Alternative #1 (LINDO-input)

- $x_1 =$ # of shuttles running on Sun-Wed shift
- $x_2 =$ # of shuttles running on Thurs-Sat
- $x_3 =$ # of larger shuttles running on Sun-Wed
- $x_4 =$ # of larger shuttles running on Thurs-Sat

Shuttle-UM Problem, LP formulation in LINDO

$max \ 0.50x_1 + 0.25x_2 + 0.10x_3 + 0.15x_4$  

$\text{s.t.}$

$c_1: 69x_1 + 92x_3 \geq 48$  

$c_2: 69x_2 + 92x_4 \geq 81$  

$c_3: 10200x_1+7650x_2+11087x_3+8315x_4 \leq 52000$  

$c_4: x_1 \geq 1$  

$c_5: x_2 \geq 3$  

$c_6: x_3, x_4 \geq 0$  

End

$gin x_1$

$gin x_2$

$gin x_3$

$gin x_4$
Alternative #1 (LINDO-output)

LP OPTIMUM FOUND AT STEP  5
OBJECTIVE VALUE =  2.17401958
FIX ALL VARS.(  2) WITH RC >  0.000000E+00
NEW INTEGER SOLUTION OF  2.00000000  AT BRANCH  0 PIVOT  11
BOUND ON OPTIMUM:  2.000000
ENUMERATION COMPLETE. BRANCHES=  0 PIVOTS=  11
LAST INTEGER SOLUTION IS THE BEST FOUND
RE-INSTALLING BEST SOLUTION...

OBJECTIVE FUNCTION VALUE
  1)  2.000000

VARIABLE        VALUE          REDUCED COST
    X1         2.000000        -0.500000
    X2         4.000000        -0.250000
    X3         0.000000        -0.100000
    X4         0.000000        -0.150000
    X3,X4  0.000000              0.000000

ROW   SLACK OR SURPLUS     DUAL PRICES
  2)          90.000000        0.000000
  3)         195.000000        0.000000
  4)        1000.000000        0.000000
  5)          1.000000        0.000000
  6)          1.000000        0.000000
  7)          0.000000        0.000000

NO. ITERATIONS=  12
BRANCHES=  0 DETERM.=  1.000E  0
Alternative #2

- We removed stops with little to no frequency of use:
  - 1, 8, 10, 19, 25, 29, 30

- Reduced round trip time ($R$): 25min

- Frequency, Sun-Wed: 1 shuttle/ 25 min
- Frequency, Thurs-Sat: 1 shuttle/ 8.33 min
Alternative #2 (LINDO-input)

- $x_5 =$ # of stops removed during the Sun-Wed shift
- $x_6 =$ # of stops removed during the Thurs-Sat shift

$$\text{max } 3x_5 + x_6 \quad \text{! Maximize Frequency}$$

s.t.

- $c_1: 0.3375x_5 + 1.3x_6 \leq 10 \quad \text{! Dwell time constraints}$
- $c_2: x_5 \leq 7 \quad \text{! Maximum removal of stops Sun-Wed}$
- $c_3: x_6 \leq 7 \quad \text{! Maximum removal of stops Thurs-Sat}$
- $c_4: x_5, x_6 \geq 0 \quad \text{! Non-negativity constraint}$

end

gin $x_5$

gin $x_6$
Alternative #2 (LINDO-output)

- LP OPTIMUM FOUND AT STEP 2
- OBJECTIVE VALUE = 26.8750000
- NEW INTEGER SOLUTION OF 26.0000000 AT BRANCH 0 PIVOT 4
- BOUND ON OPTIMUM: 26.000000
- ENUMERATION COMPLETE. BRANCHES= 0 PIVOTS= 4
- LAST INTEGER SOLUTION IS THE BEST FOUND
- RE-INSTALLING BEST SOLUTION...
- OBJECTIVE FUNCTION VALUE
  1) 26.00000
- VARIABLE VALUE REDUCED COST
  - X5 7.0000000 3.000000
  - X6 5.0000000 1.000000
  - X5,X6 0.000000 0.000000
- ROW SLACK OR SURPLUS DUAL PRICES
  - 2) 1.137500 0.000000
  - 3) 0.000000 0.000000
  - 4) 2.000000 0.000000
  - 5) 0.000000 0.000000
- NO. ITERATIONS= 4
- BRANCHES= 0 DETERM. = 1.000E 0
Alternative #2

(+): Slightly increase frequency
(+): No additional costs
(-): Beneficial to passengers within the proximity of the available stops
(-): Increased average walking distance for other passengers not within proximity
Conclusion

(+) Frequency (Sun-Wed) = 4 shuttles/hr
(+) Frequency (Thurs-Sat) = 8 shuttles/hr
(-) Increased cost = $10,200 + $7,650 = $17,850 / semester
Within $52,000 budget

CHOOSE ALTERNATIVE #1

OPTIMAL SOLUTION!
Questions?