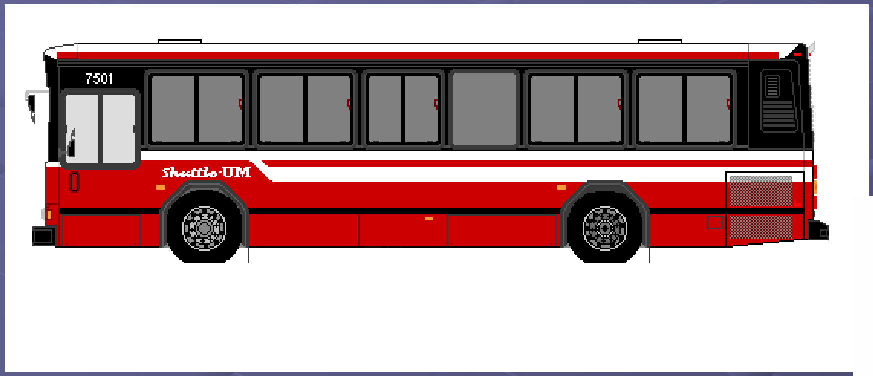
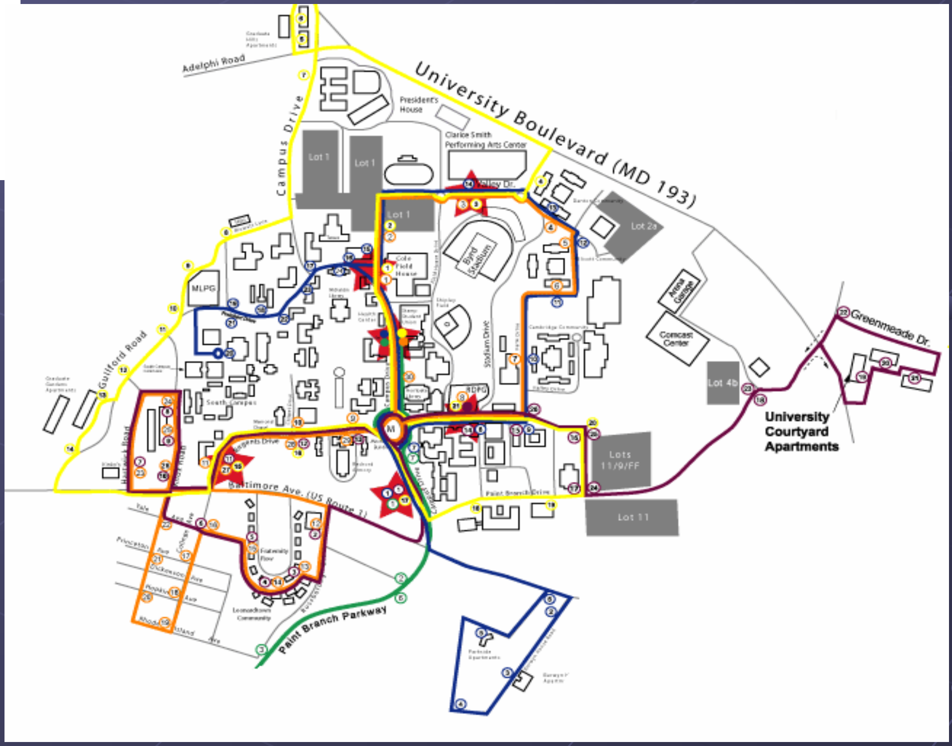
Optimizing the service of the Orange Line





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

After Midnight

	#4	#7	#10	#14	#23	#27	
AM 12:00	12:04	12:07	12:11	12:16	12:22	12:26	12:30
12:10	12:14	12:17	12:21	12:26	12:32	12:36	12:40
12:20	12:24	12:27	12:31	12:36	12:42	12:46	12:50
12:30	12:34	12:37	12:41	12:46	12:52	12:56	1:00
12:40	12:44	12:47	12:51	12:56	1:02	1:06	1:10
12:50	12:54	12:57	1:01	1:06	1:12	1:16	1:20
1:00	1:04	1:07	1:11	1:16	1:22	1:26	1:30
1:10	1:14	1:17	1:21	1:26	1:32	1:36	1:40
1:20	1:24	1:27	1:31	1:36	1:42	1:46	1:50
1:30	1:34	1:37	1:41	1:46	1:52	1:56	2:00
1:40	1:44	1:47	1:51	1:56	2:02	2:06	2:10
1:50	1:54	1:57	2:01	2:06	2:12	2:16	2:20
2:00	2:04	2:07	2:11	2:16	2:22	2:26	2:30
2:10	2:14	2:17	2:21	2:26	2:32	2:36	2:40
2:20	2:24	2:27	2:31	2:36	2:42	2:46	2:50
2:30	2:34	2:37	2:41	2:46	2:52	2:56	3:00
2:40	2:44	2:47	2:51	2:56	3:02	3:06	3:10
2:50	2:54	2:57	3:01	3:06	3:12	3:16	3:20
3:00	3:04	3:07	3:11	3:16	3:22	3:26	3:30

Shaded times operate Thursday through Saturday only.

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

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

- (-) Additional $1,552.95/semester

Alternative #1 (LINDO-input)

- x1 = # of shuttles running on Sun-Wed shift
- x2 = # of shuttles running on Thurs-Sat
- x3 = # of larger shuttles running on Sun-Wed
- x4 = # of larger shuttles running on Thurs-Sat

```
!Shuttle-UM Problem, LP formulation in LINDO
max .50x1 + .25x2 + .10x3 + .15x4              ! Maximize Frequency
s.t.
c1: 69x1 + 92x3 >= 48                          ! (Peak demand capacity Sun-Wed)
c2: 69x2 + 92x4 >= 81                          ! (Peak demand capacity Thurs-Sat)
c3: 10200x1+7650x2+11087x3+8315x4 <= 52000  ! (Cost constraint)
c4: x1 >= 1                                    ! (Sun-Wed constraint)
c5: x2 >= 3                                    ! (Thurs-Sat constraint)
c6: x3,x4 >= 0                                 ! (Non-negativity for large buses)
End
gin x1
gin x2
gin x3
gin x4
```

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)

- x5 = # of stops removed during the Sun-Wed shift
- x6 = # of stops removed during the Thurs-Sat shift

```
max 3x5 + x6                          ! Maximize Frequency
s.t.
c1: 0.3375x5 + 1.3x6 <= 10  ! Dwell time constraints
c2: x5 <= 7     ! Maximum removal of stops Sun-Wed
c3: x6 <= 7     ! Maximum removal of stops Thurs-Sat
c4: x5,x6 >= 0                        ! Non-negativity constraint
end
gin x5
gin x6
```

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: 26.00000
- 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 7.000000** -3.000000
- **X6 5.000000** -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?