Mini Project 3

Covering a schedule with buses; designing bus runs;
Covering runs with drivers; designing tasks/shifts

AC Transit serves Berkeley, Oakland, and many of the surrounding areas with almost 200 routes and a fleet of over 600 buses. The area next to Berkeley's West Gate is a major transit hub served by a BART station and 15 different bus routes.

In this project you will determine the optimal way to assign buses and drivers to three of the bus routes that serve this transit hub.

Route Characteristics

The three routes examined in this mini project are the 7, which provides service between Berkeley and El Cerrito Del Norte BART stations; the 18, which serves the Shattuck corridor and downtown Oakland; and the 52, which provides service between UC village in Albany and the UC Berkeley campus. The weekday schedules for these routes are shown in Tables 2-4.

A. For each route and direction determine the total *bus-hrs in service* per day. This will be a lower bound used for comparison for the rest of the project. What are the service peak period for each route and direction (if any)? What is maximum number of active bus loops over the day (the minimum number of buses needed) for each route? (Here the word "loop" denotes a segment between termini that a bus travels; i.e., an indivisible "bus task". In the lecture notes, with the assumption of only one terminus, a bus task is a real loop.)

B. Assuming that the three routes are treated independently, determine the maximum number of buses needed to cover the routes if deadheading between termini of the same route is allowed. You need to determine the actual number of buses needed to cover the loops (i.e., the bus tasks) for each route using the greedy algorithm. You also need to identify the runs for each bus and the total bus-hrs spent, including any dwell times not at a depot. Note, the time that a bus spends at the depot does not incur cost (i.e., does not count into the total bus-hrs). Thus, sending buses to the depot whenever possible is economical. If necessary, a bus can deadhead to the other end of its route to cover the reverse task. Times to deadhead between termini and to a depot are shown in Table 1. Compare the bus-hrs and number of buses with the lower bounds from Part A.

C. In order to decrease the wasted bus-hrs dwelling and the number of buses used, the three routes named above will use the same pool of buses to serve their routes. Determine the maximum number of buses needed to cover the system if deadheading between all terminii is allowed. You can use the same greedy method that you used in Part B. However, you will be given extra credit if you program and run an iterative covering algorithm to find a better arrangement of runs that minimizes the bus-hrs required to serve the routes. If you do this, clearly describe your algorithm (in the form of pseudo-code or flow chart). Compare the bus-hrs and number of buses with the lower bounds from Part A.

D. Cover the runs from your solution to Part C with drivers. Assume all drivers have 8-hour shifts. In addition, overtime is offered at double the wage rate. Driver changes can only

happen at the depot or the Berkeley BART station. Determine the number of drivers needed, the job for each driver, and the driver hours wasted (when a driver is not driving). You should consider using the greedy covering method from the lecture. Using a wage rate of $25/hr, what is the cost of covering the runs?

E. Repeat Part D, assuming in addition that an asymmetric work rotation is available. The drivers working on such rotation get 4 days of 9-hour shifts and 1 day with a 4-hour shift (such that each day has a ratio of 9-hour to 4-hour shifts of 4:1). In order to avoid hiring more drivers than needed, you may also use 8-hour shifts. Determine the number of drivers needed, the job for each driver, and the driver hours wasted (when a driver is not driving). Still using a wage rate of $25/hr, what is the cost of covering the runs?

F. Absenteeism can be a problem for transit agencies. If we assume that each driver has a 5% chance of skipping their assigned shift, determine how many backup drivers (who can cover any shift) the city must employ to ensure that there is 99% chance that all shifts will be covered for the work schedule you solved for in Part D.

You are to submit a formal report describing your tasks and your findings. Please *clearly state your assumptions and the method* you use to solve the problems. You may work in small groups of up to 3 people and submit a group report.

Table 1. Deadheading Time between Locations.

Travel Time (min)	To: Emeryville Depot	To: Berkeley BART	To: Del Norte BART	To: Mountain & Moraga	To: San Pablo & Marin	To: Bancroft & Telegraph	To: El Cerrito BART
From: Emeryville Depot	0	10	18	14	10	11	15
From: Berkeley BART	10	0	15	18	9	3	12
From: Del Norte BART	17	14	0	31	8	17	7
From: Mountain & Moraga	14	16	28	0	20	15	25
From: San Pablo & Marin	11	7	8	23	0	10	5
From: Bancroft & Telegraph	11	2	16	17	10	0	13
From: El Cerrito BART	14	11	6	27	5	14	0

Table 2. Schedule of Route 7.

7 Northbound		7 Southbound	
Berkeley BART	Del Norte BART	Del Norte BART	Berkeley BART
6:00 AM	6:32 AM	6:10 AM	6:44 AM
6:37 AM	7:09 AM	6:45 AM	7:19 AM

7:17 AM	7:50 AM	7:15 AM	7:50 AM
7:52 AM	8:25 AM	8:05 AM	8:40 AM
8:33 AM	9:06 AM	8:45 AM	9:20 AM
9:15 AM	9:48 AM	9:25 AM	10:00 AM
9:54 AM	10:27 AM	10:05 AM	10:40 AM
10:34 AM	11:07 AM	10:45 AM	11:20 AM
11:14 AM	11:47 AM	11:25 AM	12:00 PM
11:54 AM	12:27 PM	12:05 PM	12:40 PM
12:34 PM	1:07 PM	12:45 PM	1:20 PM
1:14 PM	1:47 PM	1:25 PM	2:00 PM
1:55 PM	2:28 PM	2:05 PM	2:40 PM
2:35 PM	3:08 PM	2:45 PM	3:20 PM
3:16 PM	3:49 PM	3:25 PM	4:00 PM
3:56 PM	4:29 PM	4:05 PM	4:40 PM
4:36 PM	5:09 PM	4:45 PM	5:20 PM
5:17 PM	5:50 PM	5:25 PM	6:00 PM
5:57 PM	6:30 PM	6:06 PM	6:40 PM
6:37 PM	7:09 PM	6:46 PM	7:20 PM
7:17 PM	7:49 PM	7:26 PM	8:00 PM
7:54 PM	8:26 PM	8:00 PM	8:34 PM

Table 3. Schedule of Route 18.

18 Northbound			18 Southbound		
Mountain & Moraga	Berkeley BART	San Pablo & Marin	San Pablo & Marin	Berkeley BART	Mountain & Moraga
5:21 AM	6:04 AM	6:17 AM	5:15 AM	5:32 AM	6:10 AM
5:36 AM	6:19 AM	6:32 AM	5:30 AM	5:47 AM	6:25 AM
5:51 AM	6:34 AM	6:47 AM	5:46 AM	6:03 AM	6:41 AM
6:06 AM	6:49 AM	7:02 AM	5:57 AM	6:16 AM	6:56 AM
6:22 AM	7:05 AM	7:18 AM	6:18 AM	6:37 AM	7:17 AM
6:37 AM	7:27 AM	7:40 AM	6:34 AM	6:53 AM	7:33 AM
6:53 AM	7:43 AM	7:56 AM	6:50 AM	7:09 AM	7:49 AM
7:08 AM	7:58 AM	8:11 AM	7:05 AM	7:24 AM	8:04 AM
7:20 AM	8:10 AM	8:23 AM	7:20 AM	7:39 AM	8:19 AM
7:29 AM	8:19 AM	8:32 AM	7:23 AM	7:47 AM	8:37 AM
7:45 AM	8:39 AM	8:54 AM	7:38 AM	8:02 AM	8:52 AM
8:01 AM	8:55 AM	9:10 AM	7:53 AM	8:17 AM	9:07 AM
8:16 AM	9:10 AM	9:25 AM	8:08 AM	8:32 AM	9:22 AM
8:31 AM	9:25 AM	9:40 AM	8:23 AM	8:47 AM	9:37 AM
8:49 AM	9:43 AM	9:58 AM	8:38 AM	9:02 AM	9:52 AM
9:04 AM	9:58 AM	10:13 AM	8:55 AM	9:19 AM	10:05 AM

9:19 AM	10:13 AM	10:28 AM	9:10 AM	9:34 AM	10:20 AM
9:34 AM	10:27 AM	10:43 AM	9:25 AM	9:49 AM	10:35 AM
9:49 AM	10:42 AM	10:58 AM	9:40 AM	10:04 AM	10:50 AM
10:04 AM	10:57 AM	11:13 AM	9:54 AM	10:18 AM	11:04 AM
10:17 AM	11:10 AM	11:26 AM	10:10 AM	10:34 AM	11:20 AM
10:32 AM	11:25 AM	11:41 AM	10:25 AM	10:49 AM	11:35 AM
10:47 AM	11:40 AM	11:56 AM	10:40 AM	11:04 AM	11:50 AM
11:02 AM	11:55 AM	12:11 PM	10:55 AM	11:19 AM	12:05 PM
11:16 AM	12:09 PM	12:25 PM	11:10 AM	11:34 AM	12:20 PM
11:32 AM	12:25 PM	12:41 PM	11:25 AM	11:49 AM	12:35 PM
11:47 AM	12:40 PM	12:56 PM	11:39 AM	12:02 PM	12:51 PM
12:02 PM	12:55 PM	1:11 PM	11:54 AM	12:17 PM	1:06 PM
12:17 PM	1:10 PM	1:26 PM	12:09 PM	12:32 PM	1:21 PM
12:32 PM	1:25 PM	1:41 PM	12:24 PM	12:47 PM	1:36 PM
12:47 PM	1:40 PM	1:56 PM	12:38 PM	1:01 PM	1:50 PM
1:03 PM	1:56 PM	2:12 PM	12:54 AM	1:17 PM	2:06 PM
1:18 PM	2:11 PM	2:27 PM	1:09 PM	1:32 PM	2:21 PM
1:33 PM	2:28 PM	2:45 PM	1:24 PM	1:47 PM	2:36 PM
1:48 PM	2:43 PM	3:00 PM	1:39 PM	2:02 PM	2:51 PM
2:02 PM	2:57 PM	3:14 PM	1:54 PM	2:17 PM	3:06 PM
2:18 PM	3:13 PM	3:30 PM	2:09 PM	2:32 PM	3:21 PM
2:33 PM	3:28 PM	3:45 PM	2:24 PM	2:48 PM	3:40 PM
2:48 PM	3:43 PM	4:00 PM	2:39 PM	3:03 PM	3:55 PM
3:03 PM	3:58 PM	4:15 PM	2:53 PM	3:17 PM	4:09 PM
3:18 PM	4:13 PM	4:30 PM	3:06 PM	3:30 PM	4:22 PM
3:33 PM	4:31 PM	4:50 PM	3:19 PM	3:43 PM	4:35 PM
3:52 PM	4:50 PM	5:09 PM	3:35 PM	3:59 PM	4:51 PM
4:07 PM	5:05 PM	5:24 PM	3:51 PM	4:16 PM	5:10 PM
4:21 PM	5:19 PM	5:38 PM	4:06 PM	4:31 PM	5:25 PM
4:34 PM	5:32 PM	5:51 PM	4:22 PM	4:47 PM	5:41 PM
4:47 PM	5:43 PM	6:00 PM	4:38 PM	5:03 PM	5:57 PM
5:03 PM	5:59 PM	6:16 PM	4:53 PM	5:18 PM	6:12 PM
5:22 PM	6:18 PM	6:35 PM	5:09 PM	5:34 PM	6:28 PM
5:37 PM	6:33 PM	6:50 PM	5:25 PM	5:50 PM	6:44 PM
5:53 PM	6:49 PM	7:06 PM	5:41 PM	6:05 PM	6:56 PM
6:09 PM	7:05 PM	7:22 PM	6:03 PM	6:27 PM	7:18 PM
6:24 PM	7:20 PM	7:37 PM	6:15 PM	6:39 PM	7:30 PM
6:40 PM	7:30 PM	7:45 PM	6:31 PM	6:55 PM	7:46 PM
6:56 PM	7:46 PM	8:01 PM	6:48 PM	7:10 PM	7:56 PM
7:08 PM	7:58 PM	8:13 PM	7:03 PM	7:25 PM	8:11 PM
7:30 PM	8:20 PM	8:35 PM	7:22 PM	7:44 PM	8:30 PM

7:42 PM	8:32 PM	8:47 PM	7:42 PM	8:04 PM	8:50 PM
8:08 PM	8:55 PM	9:10 PM	8:02 PM	8:24 PM	9:10 PM
8:23 PM	9:10 PM	9:25 PM	8:26 PM	8:48 PM	9:31 PM
8:42 PM	9:29 PM	9:44 PM	8:49 PM	9:11 PM	9:54 PM
9:02 PM	9:49 PM	10:04 PM	9:07 PM	9:29 PM	10:12 PM
9:22 PM	10:09 PM	10:24 PM	9:27 PM	9:49 PM	10:32 PM
9:43 PM	10:30 PM	10:45 PM	9:47 PM	10:09 PM	10:52 PM
10:06 PM	10:48 PM	11:01 PM	10:07 PM	10:29 PM	11:12 PM
10:36 PM	11:18 PM	11:31 PM	10:37 PM	10:59 PM	11:42 PM
11:08 PM	11:50 PM	12:03 AM	11:07 PM	11:29 PM	12:12 AM
11:38 PM	12:20 AM	12:33 AM	11:37 PM	11:59 PM	12:42 AM

Table 4. Schedule of Route 52. (To make the problem more interesting, the schedule is from the schedule of 52L last year.)

52 Northbound			52 Southbound		
Bancroft & Telegraph	University & Shattuck	El Cerrito Plaza BART	El Cerrito Plaza BART	University & Shattuck	Bancroft & Telegraph
6:00 AM	6:12 AM	6:41 AM	5:42 AM	6:21 AM	6:32 AM
6:27 AM	6:39 AM	7:16 AM	6:37 AM	7:09 AM	7:20 AM
7:00 AM	7:12 AM	7:41 AM	6:55 AM	7:27 AM	7:38 AM
7:30 AM	7:42 AM	8:19 AM	7:03 AM	7:35 AM	7:46 AM
8:00 AM	8:12 AM	8:41 AM	7:24 AM	7:56 AM	8:07 AM
8:30 AM	8:42 AM	9:13 AM	7:38 AM	8:10 AM	8:21 AM
9:00 AM	9:12 AM	9:43 AM	7:48 AM	8:20 AM	8:31 AM
9:30 AM	9:42 AM	10:13 AM	7:58 AM	8:30 AM	8:41 AM
9:58 AM	10:10 AM	10:41 AM	8:08 AM	8:41 AM	8:52 AM
10:30 AM	10:42 AM	11:13 AM	8:18 AM	8:51 AM	9:02 AM
11:00 AM	11:12 AM	11:43 AM	8:29 AM	9:02 AM	9:13 AM
11:30 AM	11:42 AM	12:12 PM	8:40 AM	9:13 AM	9:24 AM
12:00 PM	12:12 PM	12:42 PM	8:51 AM	9:24 AM	9:35 AM
12:30 PM	12:42 PM	1:12 PM	9:02 AM	9:35 AM	9:46 AM
1:00 PM	1:12 PM	1:42 PM	9:13 AM	9:46 AM	9:57 AM
1:30 PM	1:42 PM	2:12 PM	9:25 AM	9:58 AM	10:09 AM
2:00 PM	2:12 PM	2:51 PM	9:37 AM	10:10 AM	10:21 AM
2:32 PM	2:44 PM	3:15 PM	10:08 AM	10:41 AM	10:52 AM
3:02 PM	3:14 PM	3:47 PM	10:38 AM	11:11 AM	11:22 AM
3:29 PM	3:41 PM	4:14 PM	11:08 AM	11:41 AM	11:52 AM
3:44 PM	3:56 PM	4:29 PM	11:38 AM	12:11 PM	12:22 PM
3:54 PM	4:06 PM	4:39 PM	12:08 PM	12:41 PM	12:52 PM
4:04 PM	4:17 PM	4:49 PM	12:37 PM	1:10 PM	1:21 PM
4:15 PM	4:28 PM	5:00 PM	1:07 PM	1:40 PM	1:51 PM
4:25 PM	4:38 PM	5:10 PM	1:35 PM	2:08 PM	2:19 PM

4:35 PM	4:48 PM	5:19 PM	2:05 PM	2:45 PM	2:56 PM
4:45 PM	4:58 PM	5:29 PM	2:32 PM	3:12 PM	3:23 PM
4:55 PM	5:08 PM	5:39 PM	3:04 PM	3:37 PM	3:48 PM
5:05 PM	5:18 PM	5:49 PM	3:35 PM	4:08 PM	4:19 PM
5:15 PM	5:28 PM	5:59 PM	4:05 PM	4:38 PM	4:49 PM
5:25 PM	5:38 PM	6:09 PM	4:35 PM	5:08 PM	5:19 PM
5:36 PM	5:49 PM	6:20 PM	5:06 PM	5:39 PM	5:50 PM
5:46 PM	5:59 PM	6:30 PM	5:35 PM	6:08 PM	6:19 PM
5:57 PM	6:10 PM	6:41 PM	6:05 PM	6:38 PM	6:49 PM
6:10 PM	6:23 PM	6:53 PM	6:35 PM	7:08 PM	7:19 PM
6:20 PM	6:33 PM	7:03 PM	7:01 PM	7:41 PM	7:52 PM
6:29 PM	6:42 PM	7:12 PM	7:34 PM	8:14 PM	8:25 PM
6:40 PM	6:53 PM	7:23 PM	8:01 PM	8:34 PM	8:45 PM
6:55 PM	7:08 PM	7:38 PM	8:27 PM	9:00 PM	9:11 PM
7:10 PM	7:23 PM	8:01 PM	8:56 PM	9:29 PM	9:40 PM
7:25 PM	7:38 PM	8:08 PM	9:26 PM	9:59 PM	10:10 PM
7:39 PM	7:52 PM	8:22 PM	9:56 PM	10:29 PM	10:40 PM
7:58 PM	8:11 PM	8:40 PM	10:26 PM	10:59 PM	11:10 PM
8:20 PM	8:32 PM	9:01 PM	10:58 PM	11:31 PM	11:42 PM
8:51 PM	9:03 PM	9:32 PM			
9:25 PM	9:37 PM	10:06 PM			
9:55 PM	10:07 PM	10:36 PM			
10:27 PM	10:39 PM	11:08 PM			
11:01 PM	11:13 PM	11:42 PM			