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 Rockridge and El Cerrito Del Norte BART stations; the 18, which serves the Shattuck corridor and downtown Oakland; and the 52L, which provides service between El Cerrito 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 peak service times for each route and direction? What is maximum number of bus loops over the day (the minimum number of buses needed) for each route?

B. Assuming that the routes are treated independently, determine the maximum number of buses needed to cover the route if deadheading between terminii is allowed. Determine the actual number of buses needed to cover the loops for each route using the greedy algorithm; identify the runs for each bus and the total bus-hrs spent, including any dwell times not at a depot. If necessary, a bus can deadhead to the other end of its route to cover a loop. 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. Program and run an iterative covering algorithm to find the optimal arrangement of runs that minimizes the bus-hrs required to serve the routes. Compare the bus-hrs and number of buses with the lower bounds from Part A.
(Pseudocode and logic for the algorithm are included at the end of this problem statement)

D. Cover the runs from your solution to Part C. An asymmetric work rotation if offered such that each driver gets 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 addition, overtime is offered at double the wage rate. In order to avoid hiring more drivers than needed, you can also use 8-hour shifts. Drivers can only be assigned to a bus at the Depot or at 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 on a loop). Using a wage rate of $25/hr, what is the cost of covering the runs?

E. 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 E.

You are to submit a formal report describing your tasks and your findings. You may work in small groups of up to 3 people and submit a group report.

Deadheading Time	Rockridge BART	Del Norte BART	San Pablo / Marin	Moraga / Medau	Bancroft / Telegraph	El Cerrito BART	
Rockridge BART	0:00:00	0:24:00	0:14:00	0:06:00	0:07:00	0:18:00	**Route 7**
Del Norte BART	0:24:00	0:00:00	0:07:00	0:25:00	0:18:00	0:08:00	
San Pablo/Marin	0:14:00	0:07:00	0:00:00	0:19:00	0:10:00	0:04:00	**Route 18**
Moraga/Medau	0:06:00	0:25:00	0:19:00	0:00:00	0:12:00	0:19:00	
Bancroft/Telegraph	0:07:00	0:18:00	0:10:00	0:12:00	0:00:00	0:14:00	**Route 52L**
El Cerrito BART	0:18:00	0:08:00	0:04:00	0:19:00	0:14:00	0:00:00	
Emeryville Depot	0:08:00	0:16:00	0:09:00	0:16:00	0:11:00	0:13:00	**Depot**

Table 1. Deadheading Travel Time between locations

	Northbound				Southbound			
Route	Rockridge BART	Berkeley BART	Del Norte BART	Bus #	Del Norte BART	Berkeley BART	Rockridge BART	Bus #
7	6:22 AM	6:36 AM	7:08 AM		6:18 AM	6:52 AM	7:10 AM	
7	6:42 AM	6:56 AM	7:28 AM		6:36 AM	7:10 AM	7:28 AM	
7	7:05 AM	7:19 AM	7:51 AM		6:53 AM	7:28 AM	7:48 AM	
7	7:25 AM	7:41 AM	8:17 AM		7:14 AM	7:49 AM	8:09 AM	
7	7:45 AM	8:01 AM	8:37 AM		7:34 AM	8:09 AM	8:29 AM	
7	8:05 AM	8:21 AM	8:57 AM		7:57 AM	8:32 AM	8:52 AM	
7	8:24 AM	8:42 AM	9:19 AM		8:25 AM	9:00 AM	9:22 AM	
7	8:45 AM	9:03 AM	9:40 AM		8:55 AM	9:30 AM	9:52 AM	
7	9:05 AM	9:23 AM	10:00 AM		9:25 AM	10:00 AM	10:22 AM	
7	9:30 AM	9:48 AM	10:25 AM		9:54 AM	10:29 AM	10:51 AM	
7	10:00 AM	10:18 AM	10:55 AM		10:24 AM	10:59 AM	11:21 AM	
7	10:30 AM	10:48 AM	11:25 AM		10:54 AM	11:29 AM	11:51 AM	
7	11:00 AM	11:18 AM	11:55 AM		11:24 AM	11:59 AM	12:21 PM	
7	11:30 AM	11:48 AM	12:25 PM		11:54 AM	12:29 PM	12:51 PM	
7	12:00 PM	12:18 PM	12:55 PM		12:24 PM	12:59 PM	1:21 PM	
7	12:30 PM	12:48 PM	1:25 PM		12:54 PM	1:29 PM	1:51 PM	
7	1:00 PM	1:18 PM	1:55 PM		1:24 PM	1:59 PM	2:21 PM	
7	1:30 PM	1:48 PM	2:25 PM		1:53 PM	2:28 PM	2:50 PM	
7	1:57 PM	2:15 PM	2:52 PM		2:24 PM	2:59 PM	3:21 PM	
7	2:27 PM	2:45 PM	3:22 PM		2:50 PM	3:25 PM	3:47 PM	
7	2:56 PM	3:14 PM	3:51 PM		3:15 PM	3:50 PM	4:12 PM	
7	3:27 PM	3:45 PM	4:22 PM		3:37 PM	4:12 PM	4:34 PM	
7	3:58 PM	4:16 PM	4:53 PM		3:57 PM	4:32 PM	4:54 PM	
7	4:21 PM	4:39 PM	5:16 PM		4:19 PM	4:54 PM	5:14 PM	
7	4:46 PM	5:02 PM	5:38 PM		4:39 PM	5:14 PM	5:34 PM	
7	5:06 PM	5:22 PM	5:58 PM		4:59 PM	5:34 PM	5:54 PM	
7	5:26 PM	5:42 PM	6:18 PM		5:22 PM	5:57 PM	6:17 PM	
7	5:46 PM	6:02 PM	6:38 PM		5:44 PM	6:19 PM	6:39 PM	
7	6:06 PM	6:22 PM	6:58 PM		6:05 PM	6:40 PM	7:00 PM	
7	6:28 PM	6:44 PM	7:20 PM		6:35 PM	7:10 PM	7:30 PM	
7	6:55 PM	7:16 PM	7:52 PM		7:05 PM	7:43 PM	8:03 PM	
7	7:25 PM	7:46 PM	8:22 PM		7:35 PM	8:13 PM	8:33 PM	
7	7:55 PM	8:16 PM	8:52 PM		8:05 PM	8:43 PM	9:03 PM	

Table 2. Route 7 Schedule

	Northbound				Southbound			
Route	Bancroft Way & Telegraph Ave.	Berkeley BART	El Cerrito Plaza BART	Bus #	El Cerrito Plaza BART	Berkeley BART	Bancroft Way & Telegraph Ave.	Bus #
52L	6:00 AM	6:12 AM	6:41 AM		5:42 AM	6:21 AM	6:32 AM	
52L	6:27 AM	6:39 AM	7:16 AM		6:37 AM	7:09 AM	7:20 AM	
52L	7:00 AM	7:12 AM	7:41 AM		6:55 AM	7:27 AM	7:38 AM	
52L	7:30 AM	7:42 AM	8:19 AM		7:03 AM	7:35 AM	7:46 AM	
52L	8:00 AM	8:12 AM	8:41 AM		7:24 AM	7:56 AM	8:07 AM	
52L	8:30 AM	8:42 AM	9:13 AM		7:38 AM	8:10 AM	8:21 AM	
52L	9:00 AM	9:12 AM	9:43 AM		7:48 AM	8:20 AM	8:31 AM	
52L	9:30 AM	9:42 AM	10:13 AM		7:58 AM	8:30 AM	8:41 AM	
52L	9:58 AM	10:10 AM	10:41 AM		8:08 AM	8:41 AM	8:52 AM	
52L	10:30 AM	10:42 AM	11:13 AM		8:18 AM	8:51 AM	9:02 AM	
52L	11:00 AM	11:12 AM	11:43 AM		8:29 AM	9:02 AM	9:13 AM	
52L	11:30 AM	11:42 AM	12:12 PM		8:40 AM	9:13 AM	9:24 AM	
52L	12:00 PM	12:12 PM	12:42 PM		8:51 AM	9:24 AM	9:35 AM	
52L	12:30 PM	12:42 PM	1:12 PM		9:02 AM	9:35 AM	9:46 AM	
52L	1:00 PM	1:12 PM	1:42 PM		9:13 AM	9:46 AM	9:57 AM	
52L	1:30 PM	1:42 PM	2:12 PM		9:25 AM	9:58 AM	10:09 AM	
52L	2:00 PM	2:12 PM	2:51 PM		9:37 AM	10:10 AM	10:21 AM	
52L	2:32 PM	2:44 PM	3:15 PM		10:08 AM	10:41 AM	10:52 AM	
52L	3:02 PM	3:14 PM	3:47 PM		10:38 AM	11:11 AM	11:22 AM	
52L	3:29 PM	3:41 PM	4:14 PM		11:08 AM	11:41 AM	11:52 AM	
52L	3:44 PM	3:56 PM	4:29 PM		11:38 AM	12:11 PM	12:22 PM	
52L	3:54 PM	4:06 PM	4:39 PM		12:08 PM	12:41 PM	12:52 PM	
52L	4:04 PM	4:17 PM	4:49 PM		12:37 PM	1:10 PM	1:21 PM	
52L	4:15 PM	4:28 PM	5:00 PM		1:07 PM	1:40 PM	1:51 PM	
52L	4:25 PM	4:38 PM	5:10 PM		1:35 PM	2:08 PM	2:19 PM	
52L	4:35 PM	4:48 PM	5:19 PM		2:05 PM	2:45 PM	2:56 PM	
52L	4:45 PM	4:58 PM	5:29 PM		2:32 PM	3:12 PM	3:23 PM	
52L	4:55 PM	5:08 PM	5:39 PM		3:04 PM	3:37 PM	3:48 PM	
52L	5:05 PM	5:18 PM	5:49 PM		3:35 PM	4:08 PM	4:19 PM	
52L	5:15 PM	5:28 PM	5:59 PM		4:05 PM	4:38 PM	4:49 PM	
52L	5:25 PM	5:38 PM	6:09 PM		4:35 PM	5:08 PM	5:19 PM	
52L	5:36 PM	5:49 PM	6:20 PM		5:06 PM	5:39 PM	5:50 PM	
52L	5:46 PM	5:59 PM	6:30 PM		5:35 PM	6:08 PM	6:19 PM	
52L	5:57 PM	6:10 PM	6:41 PM		6:05 PM	6:38 PM	6:49 PM	
52L	6:10 PM	6:23 PM	6:53 PM		6:35 PM	7:08 PM	7:19 PM	
52L	6:20 PM	6:33 PM	7:03 PM		7:01 PM	7:41 PM	7:52 PM	
52L	6:29 PM	6:42 PM	7:12 PM		7:34 PM	8:14 PM	8:25 PM	
52L	6:40 PM	6:53 PM	7:23 PM		8:01 PM	8:34 PM	8:45 PM	
52L	6:55 PM	7:08 PM	7:38 PM		8:27 PM	9:00 PM	9:11 PM	
52L	7:10 PM	7:23 PM	8:01 PM		8:56 PM	9:29 PM	9:40 PM	
52L	7:25 PM	7:38 PM	8:08 PM		9:26 PM	9:59 PM	10:10 PM	
52L	7:39 PM	7:52 PM	8:22 PM		9:56 PM	10:29 PM	10:40 PM	
52L	7:58 PM	8:11 PM	8:40 PM		10:26 PM	10:59 PM	11:10 PM	
52L	8:20 PM	8:32 PM	9:01 PM		10:58 PM	11:31 PM	11:42 PM	
52L	8:51 PM	9:03 PM	9:32 PM					
52L	9:25 PM	9:37 PM	10:06 PM					
52L	9:55 PM	10:07 PM	10:36 PM					
52L	10:27 PM	10:39 PM	11:08 PM					
52L	11:01 PM	11:13 PM	11:42 PM					

Table 4. Route 52L Schedule

	Eastbound				Westbound			
Route	San Pablo Ave. & Marin Ave.	Berkeley BART	Moraga Ave. & Medau Pl.	Bus #	Moraga Ave. & Medau Pl.	Berkeley BART	San Pablo Ave. & Marin Ave.	Bus #
18	5:07 AM	5:28 AM	6:17 AM		5:29 AM	6:14 AM	6:29 AM	
18	5:38 AM	5:59 AM	6:48 AM		5:44 AM	6:29 AM	6:44 AM	
18	6:03 AM	6:26 AM	7:17 AM		5:59 AM	6:44 AM	6:59 AM	
18	6:19 AM	6:42 AM	7:33 AM		6:14 AM	6:59 AM	7:14 AM	
18	6:35 AM	6:58 AM	7:49 AM		6:29 AM	7:14 AM	7:29 AM	
18	6:50 AM	7:13 AM	8:04 AM		6:40 AM	7:30 AM	7:45 AM	
18	7:05 AM	7:28 AM	8:19 AM		6:55 AM	7:45 AM	8:00 AM	
18	7:20 AM	7:43 AM	8:37 AM		7:10 AM	8:00 AM	8:15 AM	
18	7:35 AM	7:58 AM	8:52 AM		7:21 AM	8:11 AM	8:26 AM	
18	7:50 AM	8:13 AM	9:07 AM		7:32 AM	8:28 AM	8:44 AM	
18	8:05 AM	8:28 AM	9:22 AM		7:48 AM	8:44 AM	9:00 AM	
18	8:20 AM	8:43 AM	9:37 AM		8:03 AM	8:59 AM	9:15 AM	
18	8:35 AM	8:58 AM	9:52 AM		8:18 AM	9:14 AM	9:30 AM	
18	8:46 AM	9:09 AM	10:03 AM		8:34 AM	9:30 AM	9:46 AM	
18	8:59 AM	9:22 AM	10:16 AM		8:51 AM	9:47 AM	10:03 AM	
18	9:17 AM	9:40 AM	10:34 AM		9:06 AM	10:02 AM	10:18 AM	
18	9:32 AM	9:55 AM	10:49 AM		9:21 AM	10:17 AM	10:33 AM	
18	9:47 AM	10:10 AM	11:04 AM		9:36 AM	10:30 AM	10:46 AM	
18	10:02 AM	10:25 AM	11:19 AM		9:51 AM	10:45 AM	11:01 AM	
18	10:17 AM	10:40 AM	11:34 AM		10:06 AM	11:00 AM	11:16 AM	
18	10:35 AM	10:58 AM	11:52 AM		10:15 AM	11:09 AM	11:25 AM	
18	10:50 AM	11:13 AM	12:07 PM		10:33 AM	11:27 AM	11:43 AM	
18	11:05 AM	11:28 AM	12:22 PM		10:48 AM	11:42 AM	11:58 AM	
18	11:20 AM	11:43 AM	12:37 PM		11:03 AM	11:57 AM	12:13 PM	
18	11:32 AM	11:56 AM	12:55 PM		11:18 AM	12:12 PM	12:28 PM	
18	11:47 AM	12:11 PM	1:10 PM		11:36 AM	12:30 PM	12:46 PM	
18	12:02 PM	12:26 PM	1:25 PM		11:51 AM	12:45 PM	1:01 PM	
18	12:17 PM	12:41 PM	1:40 PM		12:06 PM	1:00 PM	1:16 PM	
18	12:32 PM	12:56 PM	1:55 PM		12:21 PM	1:15 PM	1:31 PM	
18	12:47 PM	1:11 PM	2:10 PM		12:36 PM	1:30 PM	1:46 PM	
18	1:02 PM	1:26 PM	2:25 PM		12:53 PM	1:47 PM	2:03 PM	
18	1:17 PM	1:41 PM	2:40 PM		1:08 PM	2:02 PM	2:18 PM	
18	1:32 PM	1:56 PM	2:55 PM		1:23 PM	2:17 PM	2:33 PM	
18	1:47 PM	2:11 PM	3:10 PM		1:38 PM	2:32 PM	2:48 PM	
18	2:02 PM	2:26 PM	3:25 PM		1:53 PM	2:47 PM	3:03 PM	
18	2:17 PM	2:41 PM	3:42 PM		2:08 PM	3:02 PM	3:18 PM	
18	2:32 PM	2:56 PM	3:57 PM		2:23 PM	3:17 PM	3:33 PM	
18	2:47 PM	3:11 PM	4:12 PM		2:38 PM	3:32 PM	3:48 PM	
18	3:02 PM	3:26 PM	4:27 PM		2:53 PM	3:47 PM	4:03 PM	
18	3:17 PM	3:41 PM	4:42 PM		3:08 PM	4:02 PM	4:18 PM	
18	3:31 PM	3:55 PM	4:56 PM		3:23 PM	4:17 PM	4:33 PM	
18	3:51 PM	4:13 PM	5:10 PM		3:39 PM	4:34 PM	4:52 PM	
18	4:07 PM	4:29 PM	5:26 PM		3:54 PM	4:49 PM	5:07 PM	
18	4:23 PM	4:45 PM	5:42 PM		4:09 PM	5:04 PM	5:22 PM	
18	4:38 PM	5:00 PM	5:57 PM		4:24 PM	5:19 PM	5:37 PM	
18	4:53 PM	5:15 PM	6:12 PM		4:39 PM	5:34 PM	5:52 PM	
18	5:09 PM	5:31 PM	6:28 PM		4:55 PM	5:49 PM	6:07 PM	
18	5:25 PM	5:47 PM	6:44 PM		5:09 PM	6:03 PM	6:21 PM	
18	5:46 PM	6:08 PM	6:59 PM		5:25 PM	6:19 PM	6:37 PM	
18	6:04 PM	6:26 PM	7:17 PM		5:41 PM	6:33 PM	6:51 PM	
18	6:23 PM	6:45 PM	7:36 PM		5:56 PM	6:48 PM	7:06 PM	
18	6:41 PM	7:03 PM	7:54 PM		6:11 PM	7:01 PM	7:19 PM	
18	7:01 PM	7:23 PM	8:13 PM		6:27 PM	7:19 PM	7:37 PM	
18	7:20 PM	7:42 PM	8:32 PM		6:43 PM	7:29 PM	7:45 PM	
18	7:40 PM	8:02 PM	8:52 PM		6:58 PM	7:43 PM	7:58 PM	
18	8:00 PM	8:22 PM	9:12 PM		7:14 PM	7:59 PM	8:14 PM	
18	8:22 PM	8:44 PM	9:32 PM		7:33 PM	8:18 PM	8:33 PM	
18	8:42 PM	9:04 PM	9:52 PM		7:53 PM	8:37 PM	8:52 PM	
18	9:04 PM	9:26 PM	10:14 PM		8:12 PM	8:56 PM	9:11 PM	
18	9:24 PM	9:46 PM	10:34 PM		8:31 PM	9:15 PM	9:30 PM	
18	9:44 PM	10:06 PM	10:54 PM		8:51 PM	9:35 PM	9:50 PM	
18	10:04 PM	10:26 PM	11:14 PM		9:11 PM	9:55 PM	10:10 PM	
18	10:24 PM	10:46 PM	11:34 PM		9:31 PM	10:15 PM	10:30 PM	
					9:51 PM	10:35 PM	10:50 PM	
					10:13 PM	10:54 PM	11:09 PM	
					10:33 PM	11:14 PM	11:29 PM	
					10:53 PM	11:34 PM	11:49 PM	

Table 3. Route 18 Schedule

Pseudocode and Logic for Iterative Covering Algorithm

Define Variable Type Loop
    Start *as Time*
    StartLocation *as String*
    End *as Time*
    EndLocation *as String*

Define Variable Type Bus
    Run *as Loop Array*

Main Program*()*

Load the Loops into a Loop array ***ScheduleData****()*

Create a bus array ***Fleet****()*

Create a test bus array ***TestFleet****()*

Iterate through ***ScheduleData****(****j****)*

    If there is no bus at the depot then create one in ***Fleet****()*

    Iterate through ***Fleet****(****i****)*

        Reinitialize ***TestFleet****() to* ***Fleet****()*

        If current bus is feasible with ***Feasible****(****Fleet****(****i****),* ***ScheduleData****(****j****)) then*

            Assign ***ScheduleData****(****j****) to* ***TestFleet****(****i****)*

            Run ***GreedyAlgorithm****(****j+1****,* ***TestFleet****)*

            Save cost of result ***CheckCost****(****TestFleet****)*

        Else

            Assign very high cost to infeasible assignment

        Find lowest cost assignment ***i***

        Assign ***ScheduleData****(****j****) to* ***Fleet****(****i****)*

    End ***Fleet****(****i****) iteration*

End ***ScheduleData****(****j****) iteration*

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*Function **GreedyAlgorithm**(**StartRun**, **TestFleet**)*

*Iterate through **ScheduleData(j)** starting at **StartRun***

*If there is no bus at the depot then create one in **TestFleet**()*

*Iterate through **TestFleet(i)***

*If current bus is feasible with **Feasible**(**Fleet(i)**, **ScheduleData(j)**) then*

*Assign **ScheduleData(j)** to **TestFleet(i)***

Exit Loop

*End **TestFleet(i)** iteration*

*End **ScheduleData(j)** iteration*

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*Function **Feasible**(**Loop**, **Bus**) as Boolean*

*If **Bus** has never been assigned anything then Return **True***

*If **Bus** can travel from its last location to the start location of **Loop** before the start time of **Loop** then*

*Return **True***

Else

*Return **False***

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*Function **CheckCost** (**TestFleet**) as Integer*

*Iterate through **TestFleet(i)***

*Increase cost by the time between the start time of **TestFleet(i)**'s first loop and end time of **TestFleet(i)**'s last loop*

*Increase cost by time to deadhead from the depot to the start location of **TestFleet(i)**'s first loop*

*Increase cost by time to deadhead from the start location of **TestFleet(i)**'s last loop to the depot*

*Iterate through **TestFleet(i).Run(r)***

If the dwell time between loops is longer than the time to deadhead to the depot from the end location and back to the start location of the next then

Decrease the cost by the time spent at the depot

*End **TestFleet(i).Run(r)** iteration*

*End **TestFleet(i)** iteration*