

Part 1a: Analysis of the Status Quo

As is, the total cost of operations is \$2853.86. All routes for problem 1a are shown in Appendix A. Depot N has 3 routes starting there and Depot S has 4. The length, duration, cost and vehicle capacity utilization of each route is shown in Table 1.

Table 1

	Depots_n	Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 8...	8124.126	13.420	442.926	15.0	1.000	conventional
1	depS	[depS, 5771797f-6a63-4ef4-abe9-827876aeebf1, 3...	6817.557	13.373	420.744	15.0	1.000	conventional
2	depS	[depS, bfc29e7d-e106-4e2c-8895-df3e9bbfd649, c...	14112.610	13.638	544.594	15.0	1.000	conventional
3	depS	[depS, d1830b2f-bfb4-4a00-8176-9e8753ace53f, 9...	3129.607	7.114	235.632	8.0	0.533	conventional
4	depN	[depN, db2beaa7-13c1-4424-a04c-158a176845e7, 0...	9078.831	13.455	459.134	15.0	1.000	conventional
5	depN	[depN, d1dccda7-d7bf-453d-b065-6fcbe6001e1b, a...	6945.237	10.503	365.411	14.0	0.933	conventional
6	depN	[depN, 81ae301f-e02f-4868-bf37-9b5d135eea7f, d...	8123.778	10.545	385.420	15.0	1.000	conventional

The average length, duration, cost, and vehicle utilization per depot is shown in Table 2.

Table 2

	Length	Duration	Cost	Demand	Utilization
Depots_n					
depN	8049.282	11.501	403.322	14.667	0.978
depS	8045.975	11.886	410.974	13.250	0.883

The Capacity Utilizations of Each Vehicle:

conventional vehicle with utilization: 1.0
 conventional vehicle with utilization: 1.0
 conventional vehicle with utilization: 1.0
 conventional vehicle with utilization: 0.53
 conventional vehicle with utilization: 1.0
 conventional vehicle with utilization: 0.93
 conventional vehicle with utilization: 1.0

All other vehicles have zero utilization

Part 1b: Working Hour Restrictions

With working restrictions, the total cost of operations is \$3502.22, which is a significant increase. We can expect a more constrained optimization problem to have a worse objective value, or remain the same. We also see an increase in the number of required routes to complete all deliveries in one day. All routes for problem 1b are shown in Appendix A. Depot N has 5 routes starting there and Depot S has 7. The length, duration, cost, and vehicle capacity utilization of each route is shown in Table 3.

Table 3

	Depots_n	Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, f0250c9a-e0f9-4dcd-bc00-9d16529c1071, 5...	10038.704	7.365	352.930	8.0	0.533	conventional
1	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 8...	5718.482	7.208	279.584	8.0	0.533	conventional
2	depS	[depS, 5771797f-6a63-4ef4-abe9-827876aeebf1, 3...	6754.687	6.371	279.676	7.0	0.467	conventional
3	depS	[depS, a5bb2e12-d54b-49c4-bf2c-f53158622169, f...	4085.486	7.149	251.860	8.0	0.533	conventional
4	depS	[depS, bfc29e7d-e106-4e2c-8895-df3e9bbfd649, c...	13985.504	7.509	419.936	8.0	0.533	conventional
5	depS	[depS, d1830b2f-bfb4-4a00-8176-9e8753ace53f, c...	3129.607	6.239	218.132	7.0	0.467	conventional
6	depS	[depS, c884efba-7538-423f-b9bf-58a80ad1d032, 2...	6072.763	6.346	268.099	7.0	0.467	conventional
7	depN	[depN, a55626c3-50ea-4ada-a1b1-dee9231c0d68, 5...	6945.237	7.878	312.911	11.0	0.733	conventional
8	depN	[depN, 1b2a52ca-6048-47be-85ae-ed6968f828ec, d...	6423.743	5.484	256.558	6.0	0.400	conventional
9	depN	[depN, db2beaa7-13c1-4424-a04c-158a176845e7, a...	7649.081	7.278	312.361	8.0	0.533	conventional
10	depN	[depN, d1dccda7-d7bf-453d-b065-6fcb6001e1b, 0...	3285.503	7.744	250.779	12.0	0.800	conventional
11	depN	[depN, 04a590fc-f38f-48d7-b0f7-b8008e2b65dc, d...	7915.858	6.413	299.390	7.0	0.467	conventional

The average length, duration, cost, and vehicle utilization per depot is shown in Table 4. Notice that average vehicle utilization has decreased substantially.

Table 4

	Length	Duration	Cost	Demand	Utilization
Depots_n					
depN	6443.884	6.959	286.400	8.800	0.587
depS	7112.176	6.884	295.745	7.571	0.505

Capacity Utilizations of Each Vehicle:

conventional vehicle with utilization: 0.53
 conventional vehicle with utilization: 0.53
 conventional vehicle with utilization: 0.47
 conventional vehicle with utilization: 0.53

conventional vehicle with utilization: 0.53
conventional vehicle with utilization: 0.47
conventional vehicle with utilization: 0.47
conventional vehicle with utilization: 0.73
conventional vehicle with utilization: 0.4
conventional vehicle with utilization: 0.53
conventional vehicle with utilization: 0.8
conventional vehicle with utilization: 0.47

All other vehicles have zero utilization

Part 2: Fleet Replacement with Light Electric Freight Vehicles (LEFVs)

While using only LEFVs, the total cost of operations is \$ \$3569.51. Given this is a marginal increase in operational cost, it is likely worth it to reduce the carbon footprint of the company. However, overhauling an entire fleet at once is risky. Therefore, I recommend rolling out LEFVs slowly, and incorporating a hybrid solution in the meantime. All routes for problem 2 are shown in Appendix B. Depot N has 6 routes starting there and Depot S has 7. The length, duration, cost and vehicle capacity utilization of each route is shown in Table 5.

Table 5

	Depots_n		Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, 96cefc25-f246-4352-b000-795015d25dba, d...		3129.607	7.250	230.234	8.0	0.8	LEFV
1	depS	[depS, f0250c9a-e0f9-4dcd-bc00-9d16529c1071, b...		9440.155	7.755	336.567	8.0	0.8	LEFV
2	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 5...		7672.343	7.614	306.779	8.0	0.8	LEFV
3	depS	[depS, 5b9b3014-9967-4701-be4f-c0cca18a2fbd, b...		9554.480	6.889	320.993	7.0	0.7	LEFV
4	depS	[depS, a5bb2e12-d54b-49c4-bf2c-f53158622169, f...		4085.486	7.327	246.340	8.0	0.8	LEFV
5	depS	[depS, c9c83319-a969-4de3-8180-527174cefa27, 9...		12904.782	6.282	359.946	6.0	0.6	LEFV
6	depS	[depS, c884efba-7538-423f-b9bf-58a80ad1d032, 2...		6409.529	7.513	285.501	8.0	0.8	LEFV
7	depN	[depN, a43968f6-9e88-49cf-b1ef-4abc87aabb8c, 6...		7597.508	7.608	305.518	8.0	0.8	LEFV
8	depN	[depN, a55626c3-50ea-4ada-a1b1-dee9231c0d68, d...		3285.503	5.263	192.861	8.0	0.8	LEFV
9	depN	[depN, db2beaa7-13c1-4424-a04c-158a176845e7, 1...		9132.831	7.731	331.388	8.0	0.8	LEFV
10	depN	[depN, d1dccda7-d7bf-453d-b065-6fcbe6001e1b, d...		1914.358	2.778	122.257	3.0	0.3	LEFV
11	depN	[depN, 09b405aa-78dd-45f3-91c2-e26c4c7b9f09, d...		3285.503	5.263	192.861	9.0	0.9	LEFV
12	depN	[depN, 81ae301f-e02f-4868-bf37-9b5d135eea7f, 0...		9541.293	7.763	338.271	8.0	0.8	LEFV

The average length, duration, cost, and vehicle utilization per depot is shown in Table 6. Since each LEFV has lower capacity, they have a higher utilization average than problem 1b.

Table 6

	Length	Duration	Cost	Demand	Utilization
Depots_n					
depN	5792.833	6.068	247.193	7.333	0.733
depS	7599.483	7.233	298.051	7.571	0.757

Capacity Utilizations of Each Vehicle:

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.7

LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.6
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.3
LEFV vehicle with utilization: 0.9
LEFV vehicle with utilization: 0.8

All other vehicles have zero utilization

Part 3a: Optimal Fleet Composition

While using both LEFVs and conventional vehicles, the total cost of operations is \$ \$3449.86. All routes for problem 3a are shown in Appendix C. The optimal fleet mix is 9 LEFVs and 3 conventional vehicles. This hybrid approach is cheaper than using all LEFVs or conventional vehicle alone. You can see in Table 8 conventional vehicles are used to deliver more on average. Depot N has 5 routes starting there, 3 LEFVs and 2 conventional vehicles, while Depot S has 7 routes, 6 LEFVs and 1 conventional vehicle. The length, duration, cost and vehicle capacity utilization of each route is shown in Table 7.

Table 7

	Depots_n	Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, bfc29e7d-e106-4e2c-8895-df3e9bbfd649, c...	13985.504	7.509	419.936	8.0	0.533	conventional
1	depS	[depS, f0250c9a-e0f9-4dcd-bc00-9d16529c1071, 5...	10038.704	7.803	346.652	8.0	0.800	LEFV
2	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 8...	5718.482	7.457	273.856	8.0	0.800	LEFV
3	depS	[depS, 5771797f-6a63-4ef4-abe9-827876aeebf1, 3...	6754.687	6.665	273.816	7.0	0.700	LEFV
4	depS	[depS, a5bb2e12-d54b-49c4-bf2c-f53158622169, f...	4085.486	7.327	246.340	8.0	0.800	LEFV
5	depS	[depS, d1830b2f-bfb4-4a00-8176-9e8753ace53f, c...	3129.607	6.375	212.734	7.0	0.700	LEFV
6	depS	[depS, c884efba-7538-423f-b9bf-58a80ad1d032, 2...	6072.763	6.611	262.326	7.0	0.700	LEFV
7	depN	[depN, a55626c3-50ea-4ada-a1b1-dee9231c0d68, 5...	6945.237	7.878	312.911	11.0	0.733	conventional
8	depN	[depN, d1ccda7-d7bf-453d-b065-6fcbe6001e1b, 0...	3285.503	7.744	250.779	12.0	0.800	conventional
9	depN	[depN, 1b2a52ca-6048-47be-85ae-ed6968f828ec, d...	6423.743	5.764	250.740	6.0	0.600	LEFV
10	depN	[depN, db2beaa7-13c1-4424-a04c-158a176845e7, a...	7649.081	7.612	306.387	8.0	0.800	LEFV
11	depN	[depN, 04a590fc-f38f-48d7-b0f7-b8008e2b65dc, d...	7915.858	6.758	293.382	7.0	0.700	LEFV

The average length, duration, cost, and vehicle utilization per depot per vehicle type is shown in Table 8.

Table 8

Depots_n	Vehicle_Type	Length	Duration	Cost	Demand	Utilization
depN	LEFV	7329.561	6.711	283.503	7.0	0.700
	conventional	5115.370	7.811	281.845	11.5	0.767
depS	LEFV	5966.622	7.040	269.288	7.5	0.750
	conventional	13985.504	7.509	419.936	8.0	0.533

Capacity Utilizations of Each Vehicle:

conventional vehicle with utilization: 0.53

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.7
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.7
LEFV vehicle with utilization: 0.7
conventional vehicle with utilization: 0.73
conventional vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.6
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.7

All other vehicles have zero utilization

Part 3b: Supplier Issues

While using both LEFVs and conventional vehicles and having the LEFV supply limited, the total cost of operations is \$3478.10. All routes for problem 3b are shown in Appendix C. The optimal fleet mix is 4 LEFVs and 8 conventional vehicles. Naturally, we must decrease the amount of LEFVs we use. This, in turn, increased the operating cost but not by much. We do not require more routes, but conventional vehicles are used beyond their comparative advantage of capacity. Depot N has 5 routes starting there, 2 LEFVs and 3 conventional vehicles, while Depot S has 7 routes, 2 LEFVs and 5 conventional vehicles. The length, duration, cost and vehicle capacity utilization of each route is shown in Table 9.

Table 9

	Depots_n		Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, 96cefc25-f246-4352-b000-795015d25dba, d...		3129.607	7.114	235.632	8.0	0.533	conventional
1	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 8...		5718.482	6.333	262.084	7.0	0.467	conventional
2	depS	[depS, a5bb2e12-d54b-49c4-bf2c-f53158622169, f...		4085.486	7.149	251.860	8.0	0.533	conventional
3	depS	[depS, bfc29e7d-e106-4e2c-8895-df3e9bbfd649, c...		13985.504	7.509	419.936	8.0	0.533	conventional
4	depS	[depS, c884efba-7538-423f-b9bf-58a80ad1d032, 2...		6072.763	6.346	268.099	7.0	0.467	conventional
5	depS	[depS, f0250c9a-e0f9-4dcd-bc00-9d16529c1071, 5...		10038.704	7.803	346.652	8.0	0.800	LEFV
6	depS	[depS, 5771797f-6a63-4ef4-abe9-827876aeebf1, 3...		6754.687	6.665	273.816	7.0	0.700	LEFV
7	depN	[depN, 1b2a52ca-6048-47be-85ae-ed6968f828ec, d...		6423.743	5.484	256.558	6.0	0.400	conventional
8	depN	[depN, d1dccda7-d7bf-453d-b065-6fcb6001e1b, a...		3285.503	7.744	250.779	11.0	0.733	conventional
9	depN	[depN, 09b405aa-78dd-45f3-91c2-e26c4c7b9f09, 5...		6945.237	7.878	312.911	12.0	0.800	conventional
10	depN	[depN, db2beaa7-13c1-4424-a04c-158a176845e7, a...		7649.081	7.612	306.387	8.0	0.800	LEFV
11	depN	[depN, 04a590fc-f38f-48d7-b0f7-b8008e2b65dc, d...		7915.858	6.758	293.382	7.0	0.700	LEFV

The average length, duration, cost, and vehicle utilization per depot per vehicle type is shown in Table 10.

Table 10

		Length	Duration	Cost	Demand	Utilization
Depots_n	Vehicle_Type					
depN	LEFV	7782.470	7.185	299.885	7.500	0.750
	conventional	5551.494	7.035	273.416	9.667	0.644
depS	LEFV	8396.696	7.234	310.234	7.500	0.750
	conventional	6598.368	6.890	287.522	7.600	0.507

Capacity Utilizations of Each Vehicle:

conventional vehicle with utilization: 0.53

conventional vehicle with utilization: 0.47
conventional vehicle with utilization: 0.53
conventional vehicle with utilization: 0.53
conventional vehicle with utilization: 0.47
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.7
conventional vehicle with utilization: 0.4
conventional vehicle with utilization: 0.73
conventional vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.8
LEFV vehicle with utilization: 0.7

All other vehicles have zero utilization

Part 4: Time Based Restrictions for Commercial Vehicles

While using both LEFVs and conventional vehicles and having the conventional vehicle duration limited, the total cost of operations is \$3555.39. We thus use more LEFVs at the detriment of our bottom line. The conventional vehicle time limit forces it to have lower utilization as well. All routes for problem 4 are shown in Appendix D. The optimal fleet mix is 11 LEFVs and 1 conventional vehicle. Depot N has 4 routes starting there, with all LEFVs, while Depot S has 8 routes, 7 LEFVs and 1 conventional vehicle. The length, duration and cost of each route is shown in Table 11.

Table 11

Depots_n			Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, bfc29e7d-e106-4e2c-8895-df3e9bbfd649, c...		14036.558	6.635	403.302	7.0	0.467	conventional
1	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 8...		5718.482	7.457	273.856	8.0	0.800	LEFV
2	depS	[depS, 5771797f-6a63-4ef4-abe9-827876aeebf1, d...		9367.285	7.749	335.339	8.0	0.800	LEFV
3	depS	[depS, db2beaa7-13c1-4424-a04c-158a176845e7, 0...		9617.438	7.769	339.554	8.0	0.800	LEFV
4	depS	[depS, 9748e2c2-ec8d-477c-8393-9cf2f5d3b481, 5...		11372.252	7.910	369.122	8.0	0.800	LEFV
5	depS	[depS, a5bb2e12-d54b-49c4-bf2c-f53158622169, f...		4085.486	7.327	246.340	8.0	0.800	LEFV
6	depS	[depS, d1830b2f-bfb4-4a00-8176-9e8753ace53f, c...		3466.373	7.277	235.908	8.0	0.800	LEFV
7	depS	[depS, c884efba-7538-423f-b9bf-58a80ad1d032, 2...		7435.766	7.595	302.793	8.0	0.800	LEFV
8	depN	[depN, a43968f6-9e88-49cf-b1ef-4abc87aabb8c, 6...		7597.508	7.608	305.518	8.0	0.800	LEFV
9	depN	[depN, a55626c3-50ea-4ada-a1b1-dee9231c0d68, d...		3285.503	5.263	192.861	8.0	0.800	LEFV
10	depN	[depN, dacb2a58-a8b9-4195-b5b9-0f9e1b6466e4, 1...		7387.001	7.591	301.971	8.0	0.800	LEFV
11	depN	[depN, 81ae301f-e02f-4868-bf37-9b5d135eea7f, 0...		5568.298	6.320	248.826	10.0	1.000	LEFV

The average length, duration, cost, and vehicle utilization per depot per vehicle type is shown in Table 12.

Table 12

		Length	Duration	Cost	Demand	Utilization
Depots_n	Vehicle_Type					
depN	LEFV	5959.577	6.696	262.294	8.5	0.850
depS	LEFV	7294.726	7.584	300.416	8.0	0.800
	conventional	14036.558	6.635	403.302	7.0	0.467

Capacity Utilizations of Each Vehicle:

conventional vehicle with utilization: 0.47

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.8

LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 1.0

All other vehicles have zero utilization

Part 4b

While using both LEFVs and conventional vehicles and having the conventional vehicle duration limited and limited LEFVs, the total cost of operations is \$3639.72. This requires us to use more conventional vehicles and add an additional route. Average vehicle utilization substantially decreases from these restrictions. All routes for problem 4 are shown in Appendix D. The optimal fleet mix is 4 LEFVs and 9 conventional vehicles. Depot N has 5 routes starting there, 1 LEFV and 4 conventional, while Depot S has 8 routes, 3 LEFVs and 5 conventional vehicles. The length, duration and cost of each route is shown in Table 13.

Table 13

	Depots_n	Route	Length	Duration	Cost	Demand	Utilization	Vehicle_Type
0	depS	[depS, 5b9b3014-9967-4701-be4f-c0cca18a2fbd, b...	9554.480	6.472	327.209	7.0	0.467	conventional
1	depS	[depS, db2beaa7-13c1-4424-a04c-158a176845e7, 0...	7969.023	6.415	300.292	7.0	0.467	conventional
2	depS	[depS, c9c83319-a969-4de3-8180-527174cefa27, 9...	13508.825	6.616	394.343	7.0	0.467	conventional
3	depS	[depS, d1830b2f-bfb4-4a00-8176-9e8753ace53f, c...	3129.607	6.239	218.132	7.0	0.467	conventional
4	depS	[depS, c884efba-7538-423f-b9bf-58a80ad1d032, 2...	6072.763	6.346	268.099	7.0	0.467	conventional
5	depS	[depS, af0fb51e-8d06-40be-af3e-b7d79ea6d0f2, 5...	7672.343	7.614	306.779	8.0	0.800	LEFV
6	depS	[depS, a5bb2e12-d54b-49c4-bf2c-f53158622169, f...	4085.486	7.327	246.340	8.0	0.800	LEFV
7	depS	[depS, bfc29e7d-e106-4e2c-8895-df3e9bbfd649, 8...	8970.061	7.718	328.646	8.0	0.800	LEFV
8	depN	[depN, a55626c3-50ea-4ada-a1b1-dee9231c0d68, d...	3285.503	5.119	198.279	8.0	0.533	conventional
9	depN	[depN, d076114c-5812-4b34-b596-0f61e7fe08bf, 5...	9182.574	6.459	320.895	7.0	0.467	conventional
10	depN	[depN, 1b2a52ca-6048-47be-85ae-ed6968f828ec, d...	6423.743	5.484	256.558	6.0	0.400	conventional
11	depN	[depN, 09b405aa-78dd-45f3-91c2-e26c4c7b9f09, d...	3285.503	5.119	198.279	9.0	0.600	conventional
12	depN	[depN, a43968f6-9e88-49cf-b1ef-4abc87aabb8c, 6...	5838.146	7.467	275.873	8.0	0.800	LEFV

The average length, duration, cost, and vehicle utilization per depot per vehicle type is shown in Table 14.

Table 14

		Length	Duration	Cost	Demand	Utilization
Depots_n	Vehicle_Type					
depN	LEFV	5838.146	7.467	275.873	8.0	0.800
	conventional	5544.331	5.545	243.503	7.5	0.500
depS	LEFV	6909.297	7.553	293.922	8.0	0.800
	conventional	8046.940	6.418	301.615	7.0	0.467

Capacity Utilizations of Each Vehicle:

conventional vehicle with utilization: 0.47
 conventional vehicle with utilization: 0.47
 conventional vehicle with utilization: 0.47
 conventional vehicle with utilization: 0.47
 conventional vehicle with utilization: 0.47
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 LEFV vehicle with utilization: 0.8
 conventional vehicle with utilization: 0.53
 conventional vehicle with utilization: 0.47
 conventional vehicle with utilization: 0.4
 conventional vehicle with utilization: 0.6
 LEFV vehicle with utilization: 0.8

All other vehicles have zero utilization

Appendix A:**Part 1a Routes:**

Route 0:

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '8a9798bc-16f2-4a27-bf64-53b2e163d438', 'c884efba-7538-423f-b9bf-58a80ad1d032', '2268dd03-fa81-4568-9a76-74f5c9af46e6', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', 'depS']

Route 1:

['depS', '5771797f-6a63-4ef4-abe9-827876aeebf1', '33d5073c-ae32-45df-9c52-242577b29771', 'a5bb2e12-d54b-49c4-bf2c-f53158622169', 'f65120c9-f245-4c59-8530-788d72cdc406', 'f05c5f0a-a34f-41e3-9541-3c364ccc2fa8', 'depS']

Route 2:

['depS', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 3:

['depS', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', '96cefc25-f246-4352-b000-795015d25dba', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Route 4:

['depN', 'db2beaa7-13c1-4424-a04c-158a176845e7', '04a590fc-f38f-48d7-b0f7-b8008e2b65dc', 'd076114c-5812-4b34-b596-0f61e7fe08bf', 'a43968f6-9e88-49cf-b1ef-4abc87aabb8c', '68c17b8c-6678-440e-9da2-86a58e0cefaf', 'depN']

Route 5:

['depN', 'd1dccda7-d7bf-453d-b065-6fcbe6001e1b', 'a55626c3-50ea-4ada-a1b1-dee9231c0d68', '5fcbca50-6547-457a-bf01-b8dcdd2bec12', 'depN']

Route 6:

['depN', '81ae301f-e02f-4868-bf37-9b5d135eea7f', 'dacb2a58-a8b9-4195-b5b9-0f9e1b6466e4', '1b2a52ca-6048-47be-85ae-ed6968f828ec', '09b405aa-78dd-45f3-91c2-e26c4c7b9f09', 'depN']

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '8a9798bc-16f2-4a27-bf64-53b2e163d438', 'c884efba-7538-423f-b9bf-58a80ad1d032', '2268dd03-fa81-4568-9a76-74f5c9af46e6', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', 'depS']

Part 1b Routes:

Route 0:

['depS', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 1:

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '8a9798bc-16f2-4a27-bf64-53b2e163d438', '96cfc25-f246-4352-b000-795015d25dba', 'depS']

Route 2:

['depS', '5771797f-6a63-4ef4-abe9-827876aeebf1', '33d5073c-ae32-45df-9c52-242577b29771', 'f05c5f0a-a34f-41e3-9541-3c364ccc2fa8', 'depS']

Route 3:

['depS', 'a5bb2e12-d54b-49c4-bf2c-f53158622169', 'f65120c9-f245-4c59-8530-788d72cdc406', 'depS']

Route 4:

['depS', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', 'depS']

Route 5:

['depS', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Route 6:

['depS', 'c884efba-7538-423f-b9bf-58a80ad1d032', '2268dd03-fa81-4568-9a76-74f5c9af46e6', 'depS']

Route 7:

['depN', 'a55626c3-50ea-4ada-a1b1-dee9231c0d68', '5fcbca50-6547-457a-bf01-b8dcdd2bec12', 'depN']

Route 8:

['depN', '1b2a52ca-6048-47be-85ae-ed6968f828ec', 'dacb2a58-a8b9-4195-b5b9-0f9e1b6466e4', '81ae301f-e02f-4868-bf37-9b5d135eea7f', 'depN']

Route 9:

['depN', 'db2beaa7-13c1-4424-a04c-158a176845e7', 'a43968f6-9e88-49cf-b1ef-4abc87aabb8c', '68c17b8c-6678-440e-9da2-86a58e0cefaf', 'depN']

Route 10:

['depN', 'd1dccda7-d7bf-453d-b065-6fcbe6001e1b', '09b405aa-78dd-45f3-91c2-e26c4c7b9f09', 'depN']

Route 11:

['depN', '04a590fc-f38f-48d7-b0f7-b8008e2b65dc', 'd076114c-5812-4b34-b596-0f61e7fe08bf', 'depN']

['depS', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Appendix B

Part 2 Routes:

Route 0:

['depS', '96cefc25-f246-4352-b000-795015d25dba', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Route 1:

['depS', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', '8a9798bc-16f2-4a27-bf64-53b2e163d438', 'depS']

Route 2:

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '5771797f-6a63-4ef4-abe9-827876aeebf1', '3d5073c-ae32-45df-9c52-242577b29771', 'depS']

Route 3:

['depS', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 4:

['depS', 'a5bb2e12-d54b-49c4-bf2c-f53158622169', 'f65120c9-f245-4c59-8530-788d72cdc406', 'depS']

Route 5:

['depS', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', 'depS']

Route 6:

['depS', 'c884efba-7538-423f-b9bf-58a80ad1d032', '2268dd03-fa81-4568-9a76-74f5c9af46e6', 'f05c5f0a-a34f-41e3-9541-3c364ccc2fa8', 'depS']

Route 7:

['depN', 'a43968f6-9e88-49cf-b1ef-4abc87aabb8c', '68c17b8c-6678-440e-9da2-86a58e0cefaf', '5fcbca50-6547-457a-bf01-b8dcdd2bec12', 'depN']

Route 8:

['depN', 'a55626c3-50ea-4ada-a1b1-dee9231c0d68', 'depN']

Route 9:

['depN', 'db2beaa7-13c1-4424-a04c-158a176845e7', '1b2a52ca-6048-47be-85ae-ed6968f828ec', 'dacb2a58-a8b9-4195-b5b9-0f9e1b6466e4', 'depN']

Route 10:

['depN', 'd1dccda7-d7bf-453d-b065-6fcbe6001e1b', 'depN']

Route 11:

['depN', '09b405aa-78dd-45f3-91c2-e26c4c7b9f09', 'depN']

Route 12:

['depN', '81ae301f-e02f-4868-bf37-9b5d135eea7f', '04a590fc-f38f-48d7-b0f7-b8008e2b65dc', 'd076114c-5812-4b34-b596-0f61e7fe08bf', 'depN']

['depS', '96cefc25-f246-4352-b000-795015d25dba', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'c07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Appendix C

Part 3a Routes:

Route 0:

['depS', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', 'depS']

Route 1:

['depS', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 2:

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '8a9798bc-16f2-4a27-bf64-53b2e163d438', '96cfc25-f246-4352-b000-795015d25dba', 'depS']

Route 3:

['depS', '5771797f-6a63-4ef4-abe9-827876aeebf1', '33d5073c-ae32-45df-9c52-242577b29771', 'f05c5f0a-a34f-41e3-9541-3c364ccc2fa8', 'depS']

Route 4:

['depS', 'a5bb2e12-d54b-49c4-bf2c-f53158622169', 'f65120c9-f245-4c59-8530-788d72cdc406', 'depS']

Route 5:

['depS', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Route 6:

['depS', 'c884efba-7538-423f-b9bf-58a80ad1d032', '2268dd03-fa81-4568-9a76-74f5c9af46e6', 'depS']

Route 7:

['depN', 'a55626c3-50ea-4ada-a1b1-dee9231c0d68', '5fcbca50-6547-457a-bf01-b8dcdd2bec12', 'depN']

Route 8:

['depN', 'd1dccda7-d7bf-453d-b065-6fcbe6001e1b', '09b405aa-78dd-45f3-91c2-e26c4c7b9f09', 'depN']

Route 9:

['depN', '1b2a52ca-6048-47be-85ae-ed6968f828ec', 'dacb2a58-a8b9-4195-b5b9-0f9e1b6466e4', '81ae301f-e02f-4868-bf37-9b5d135eea7f', 'depN']

Route 10:

['depN', 'db2beaa7-13c1-4424-a04c-158a176845e7', 'a43968f6-9e88-49cf-b1ef-4abc87aabb8c', '68c17b8c-6678-440e-9da2-86a58e0cefaf', 'depN']

Route 11:

['depN', '04a590fc-f38f-48d7-b0f7-b8008e2b65dc', 'd076114c-5812-4b34-b596-0f61e7fe08bf', 'depN']

['depS', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', 'depS']

Part 3b Routes:

Route 0:

['depS', '96cefc25-f246-4352-b000-795015d25dba', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Route 1:

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '8a9798bc-16f2-4a27-bf64-53b2e163d438', 'depS']

Route 2:

['depS', 'a5bb2e12-d54b-49c4-bf2c-f53158622169', 'f65120c9-f245-4c59-8530-788d72cdc406', 'depS']

Route 3:

['depS', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', 'depS']

Route 4:

['depS', 'c884efba-7538-423f-b9bf-58a80ad1d032', '2268dd03-fa81-4568-9a76-74f5c9af46e6', 'depS']

Route 5:

['depS', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 6:

['depS', '5771797f-6a63-4ef4-abe9-827876aeebf1', '33d5073c-ae32-45df-9c52-242577b29771', 'f05c5f0a-a34f-41e3-9541-3c364ccc2fa8', 'depS']

Route 7:

['depN', '1b2a52ca-6048-47be-85ae-ed6968f828ec', 'dacb2a58-a8b9-4195-b5b9-0f9e1b6466e4', '81ae301f-e02f-4868-bf37-9b5d135eea7f', 'depN']

Route 8:

['depN', 'd1dccda7-d7bf-453d-b065-6fcbe6001e1b', 'a55626c3-50ea-4ada-a1b1-dee9231c0d68', 'depN']

Route 9:

['depN', '09b405aa-78dd-45f3-91c2-e26c4c7b9f09', '5fcbca50-6547-457a-bf01-b8dcdd2bec12', 'depN']

Route 10:

['depN', 'db2beaa7-13c1-4424-a04c-158a176845e7', 'a43968f6-9e88-49cf-b1ef-4abc87aabb8c', '68c17b8c-6678-440e-9da2-86a58e0cefaf', 'depN']

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['depN', '04a590fc-f38f-48d7-b0f7-b8008e2b65dc', 'd076114c-5812-4b34-b596-0f61e7fe08bf', 'depN']

['depS', '96cefc25-f246-4352-b000-795015d25dba', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'c07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

Appendix D

Part 4a Routes:

Route 0:

['depS', 'bfc29e7d-e106-4e2c-8895-df3e9bbfd649', 'c9c83319-a969-4de3-8180-527174cefa27', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 1:

['depS', 'af0fb51e-8d06-40be-af3e-b7d79ea6d0f2', '8a9798bc-16f2-4a27-bf64-53b2e163d438', '96cefc25-f246-4352-b000-795015d25dba', 'depS']

Route 2:

['depS', '5771797f-6a63-4ef4-abe9-827876aeebfl', 'd076114c-5812-4b34-b596-0f61e7fe08bf', 'depS']

Route 3:

['depS', 'db2beaa7-13c1-4424-a04c-158a176845e7', '04a590fc-f38f-48d7-b0f7-b8008e2b65dc', '33d5073c-ae32-45df-9c52-242577b29771', 'depS']

Route 4:

['depS', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'depS']

Route 5:

['depS', 'a5bb2e12-d54b-49c4-bf2c-f53158622169', 'f65120c9-f245-4c59-8530-788d72cdc406', 'depS']

Route 6:

['depS', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'f05c5f0a-a34f-41e3-9541-3c364ccc2fa8', 'depS']

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Part 4b Routes:

Route 0:

['depS', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']

Route 1:

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Route 2:

['depS', 'c9c83319-a969-4de3-8180-527174cefa27', '9748e2c2-ec8d-477c-8393-9cf2f5d3b481', 'f0250c9a-e0f9-4dcd-bc00-9d16529c1071', 'depS']

Route 3:

['depS', 'd1830b2f-bfb4-4a00-8176-9e8753ace53f', 'cc07cbb2-4ef5-4c0b-8963-829b8b68ed05', 'depS']

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Route 5:

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['depS', '5b9b3014-9967-4701-be4f-c0cca18a2fbd', 'bd08b5b9-79e6-4947-b6e7-8e7b915060df', 'depS']