Indian Institute of Technology, Kharagpur
Department of Industrial & Systems Engineering

Spring 2022-23
IM29204: Operations Research Laboratory
L-T-P : 0-0-3, Credits - 2

Lab Assignment – 8

Maximum Marks: 10

Instructions:

1. Attempt **all Questions**.
2. All questions carry **equal** marks.
3. Assume any missing data suitably and state all your assumptions clearly.
4. You need to make this submission via **MS teams**.
5. The usage of **mobile phones** and **internet** during the lab hours is **strictly prohibited** unless specially instructed.
6. Write your name and roll number inside the file. Name your file as: Your Roll No_Name. For example, if your Roll No. is 10IM9999 and your name is Ravi, then you should name your file as: **10IM9999_Ravi**
7. Submission Deadline – The file must be submitted during the lab hours. **Assignments submitted after due date and time will NOT be evaluated.**
8. Do not submit multiple files for same assignment. In case of multiple files compress them in one ".zip" file and then submit.

Problem 1. Travelling Salesman Problem (TSP) . Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city exactly once and returns to the origin city? This is called Travelling Salesman Problem (TSP).

Solve the following TSP for 20 cities. The geographical locations and distance among the locations are presented in Figure 1, and Table 1, respectively. Solve this problem on Cplex solver.

Figure 1. Locations of twenty schools that the student wants to visit

Colleges	Arizona State	Brigham Young	Brown	Colorado	Duke	Florida State	Louisiana	Louisville	Michigan	New Mexico	North Dakota	Notre Dame	Ohio	Oklahoma	Oregon	Pitt	Stanford	Texas A&M	Wisconsin	Yale
Arizona State	0	648	2625	549	2185	1898	1458	1752	1963	427	1743	1817	1899	1060	1148	2084	732	1095	1725	2524
Brigham Young	648	0	2363	481	2129	2030	1641	1594	1638	557	1214	1492	1710	1126	825	1861	811	1195	1375	2262
Brown	2625	2362	0	1965	669	1274	1541	920	744	2172	1623	875	720	1595	3085	543	3113	1734	1111	103
Colorado	549	481	1965	0	1667	1605	1194	1132	1242	431	963	1096	1280	664	1249	1464	1276	799	979	1866
Duke	2185	2129	669	1667	0	621	906	541	643	1733	1504	733	459	1187	2880	479	2791	1169	932	566
Florida State	1898	2030	1274	1605	621	0	443	662	978	1482	1669	925	839	1007	2855	929	2541	843	1107	1172
Louisiana	1458	1641	1541	1194	906	443	0	754	1106	1074	1447	976	968	638	2477	1148	2132	435	1027	1442
Louisville	1752	1594	920	1132	541	662	754	0	347	1293	1015	261	209	724	2319	389	2346	841	443	818
Michigan	1963	1638	744	1242	643	978	1106	347	0	1511	961	170	183	970	2361	287	2389	1124	388	688
New Mexico	427	557	2172	431	1733	1482	1074	1293	1511	0	1318	1363	1447	585	1378	1631	1063	641	1275	2071
North Dakota	1743	1214	1623	963	1504	1669	1447	1015	961	1318	0	813	1078	918	1571	1182	1882	1147	582	1583
Notre Dame	1817	1492	875	1096	733	925	976	261	170	1363	813	0	271	826	2215	373	2242	979	241	774
Ohio	1899	1710	720	1280	459	839	968	209	183	1447	1078	271	0	882	2453	192	2408	1049	504	621
Oklahoma	1060	1126	1595	664	1187	1007	638	724	970	585	918	826	882	0	1891	1066	1667	251	798	1495
Oregon	1148	825	3085	1249	2880	2855	2477	2319	2361	1378	1571	2215	2453	1891	0	2583	559	2042	2108	2984
Pitt	2084	1861	543	1464	479	929	1148	389	287	1631	1182	373	192	1066	2583	0	2612	1220	611	442
Stanford	732	811	3113	1276	2791	2541	2132	2346	2389	1063	1882	2242	2408	1667	559	2612	0	1701	2125	3012
Texas A&M	1095	1195	1734	799	1169	843	435	841	1124	641	1147	979	1049	251	2042	1220	1701	0	977	1634
Wisconsin	1725	1375	1111	979	932	1107	1027	443	388	1275	582	241	504	798	2108	611	2125	977	0	1011
Yale	2524	2262	103	1866	566	1172	1442	818	688	2071	1583	774	621	1495	2984	442	3012	1634	1011	0

Table 1. Distance matrix

Hint:

- Sub-tour elimination constraint:

$$u_i - u_j + n\, x_{ij} \leq n - 1;$$

  where n is the number of cities in the problem.

- TSP Formulation:

$$\text{Min } \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij}$$

  where,
  $x_{ij} = 1$; if the person moves immediately from city i to city j
  $x_{ij} = 0$; otherwise

  Subject to:

$$x_{ij} \in \{0,1\} \quad \forall\, i, j = 1,2,3, \ldots, n$$

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad \forall\, j = 1,2,3, \ldots, n$$

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad \forall\, i = 1,2,3, \ldots, n$$

$$u_i - u_j + n\, x_{ij} \leq n - 1 \quad \forall\, i = 1 \text{ to } n-1,\; j = 2 \text{ to } n$$