Name: Sand Aldagari

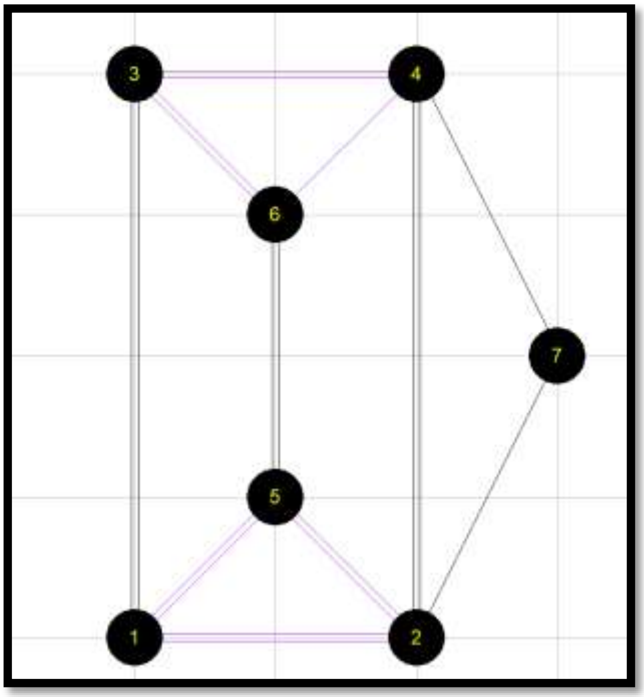
ASU ID: 1217023392

CEE 598 Topic: Traffic Simulation Modelling and Applications

Homework part II

PROBLEM (1) Node – Link Structure

The following figure shows all the links and nodes:



a)

The length in mile from node (1) to node (2) as shown below is (2 miles)

Attribute	Data
Link ID	4
name	
From Node ID	2
To Node ID	1
Type	Highway
Free Speed	35
Length	2.000
FFTT	3.429
# of Lanes	2
Lane Capacity	1800
Link Capacity	3600

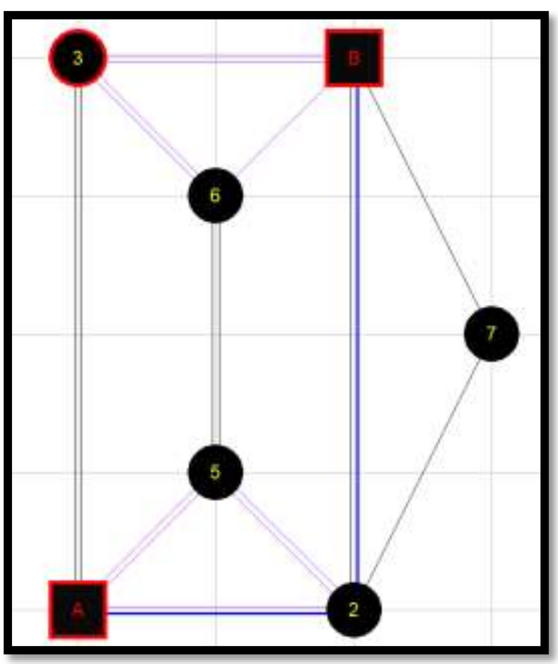
b)

we see that as shown in the link file below consistent with the inputs. As an example, if we check the information in Nexta from nod (1) to node (2) we found that the excel file and Nexta information are the same: length = 2mile, lane capacity=1800, No. of lanes =2, and so on.

link_id	name	from_node_id	to_node_id	facility_type	link_type	dir_flag	length	lanes	free_speed	capacity	geometry
1		1	2	Major arterial	2	1	2	2	35	1800	
2		1	3	Highway/Expressway	1	1	2	4	45	1800	
3		1	5	Major arterial	2	1	4	1	35	1800	
4		2	1	Major arterial	2	1	2	2	35	1800	
5		2	4	Highway/Expressway	1	1	2	4	45	1800	
6		2	5	Major arterial	2	1	2	1	35	1800	
7		3	1	Highway/Expressway	1	1	2	4	45	1800	
8		3	4	Major arterial	2	1	2	2	35	1800	
9		3	6	Major arterial	2	1	2	1	35	1800	
10		4	2	Highway/Expressway	1	1	2	4	45	1800	
11		4	3	Major arterial	2	1	2	2	35	1800	
12		5	1	Major arterial	2	1	2	1	35	1800	
13		5	2	Major arterial	2	1	2	1	35	1800	
14		5	6	Freeway	1	1	6	2	65	1800	
15		6	3	Major arterial	2	1	2	1	35	1800	
16		6	4	Major arterial	2	1	4	1	35	1800	
17		6	5	Highway/Expressway	1	1	3	2	65	1800	
18		2	7	Highway/Expressway	1	1	1	2	65	1800	
19		7	4	Highway/Expressway	1	1	1	2	65	1800	

c)

The shortest path from 1 to 4, as we can see below is: **1-2-4**



d)

- A **walk** is a sequence of nodes (n_1, n_2, ...,n_k).

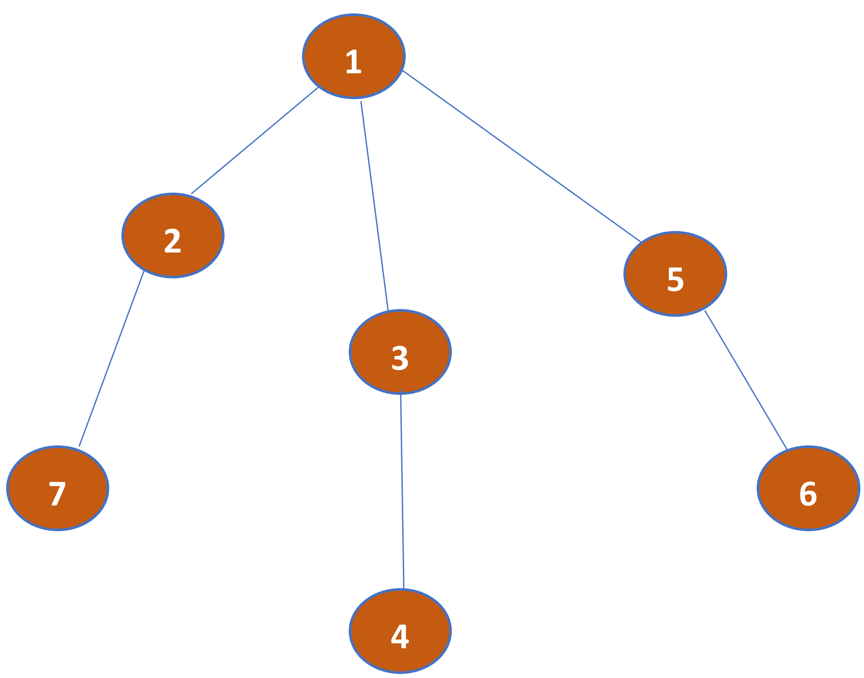
  Examples of Walk:

  - 1->3->4->7->2->1
  - 1->5->6->3->1

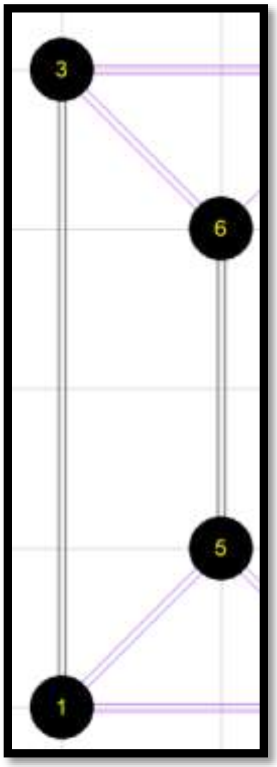
- A **tour** is similar to a path, but a tour is closed path, meaning that the first node and the final node on the path are the same node on the network. Formally, a cycle is a walk (n1, n2,...,nk) with n1 = nk, k≥3, and with no repeated nodes except n1 = nk

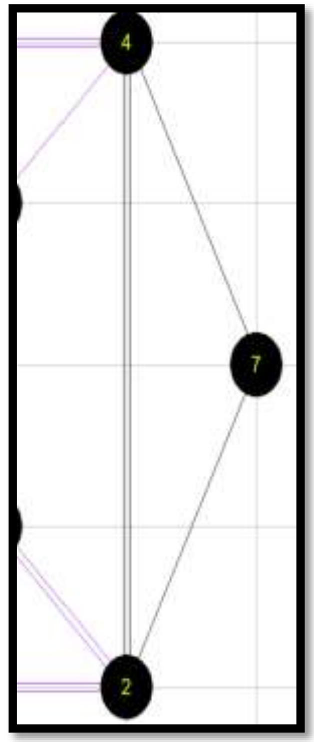
  Examples of tour:
  - 1->2->4->3->1
  - 1->3->6->5->1

- A **tree** is an acyclic connected graph. The number of links in a tree is always one less than the number of nodes.



- A **cut** is a partition of the node set N into two parts, s and $\bar{s}$=N-s. Each cut defines a set of arcs consisting of those arcs that have one endpoint in s and another endpoint in $\bar{s}$. We refer to this set of arcs as a cut and represent it by the notation [s, $\bar{s}$].





As we can see, the first cut on the left have number of nodes = s = 4. And the cut on the right side has no. of nodes = 3. So, it can be represented as [4,3] based on the number of the nodes in each cut partition starting from the left side to the right side.

- As we can see, the cut in this network include (5->6), so link sets (1->3) and (6->4) are not in cut.

PROBLEM (2) Safe Hazardous Material Transportation

So, in this problem, each segment was divided to 0.5 mile length in order to find the probability of crashes occurring on each segment. The statistics shows that Fatality rate per 100 million vehicle miles traveled in 2019 was (1.10).

$$P(crash)_{\alpha} = 1 - \left(1 - P(crash)\right)^{\alpha}$$

where P(crash) is the probability of collision per unit exposure, α is the measure of exposure (time or mileage), and $P(crash)^{\alpha}$ is the total probability of collision due to exposure.

link_type_name	length_in_mile	from_node_id	to_node_id	P (crash)
Major arterial	2	1	2	4.4E-08
Highway/Expressway	4	1	3	8.8E-08
Major arterial	1	1	5	2.2E-08
Major arterial	2	2	1	4.4E-08
Highway/Expressway	4	2	4	8.8E-08
Major arterial	1	2	5	2.2E-08
Highway/Expressway	4	3	1	8.8E-08
Major arterial	2	3	4	4.4E-08
Major arterial	1	3	6	2.2E-08
Highway/Expressway	4	4	2	8.8E-08
Major arterial	2	4	3	4.4E-08
Major arterial	1	4	6	2.2E-08
Major arterial	1	5	1	2.2E-08
Major arterial	1	5	2	2.2E-08
Freeway	2	5	6	4.4E-08
Major arterial	1	6	3	2.2E-08
Major arterial	1	6	4	2.2E-08
Highway/Expressway	2	6	5	4.4E-08

The table above shows the estimated P(crash) based on (Fatality rate per 100 million vehicle miles traveled in 2019 was (1.10) as well as dividing each segment to 0.5 mile.

-Now, log(risk(e)) can be found by log(P(crash)) for each segment and the following table showing the results

link_type_name	length_in_mile	from_node_id	to_node_id	P (crash)	Log(e)
Major arterial	2	1	2	4.4E-08	7.357
Highway/Expressway	4	1	3	8.8E-08	7.056
Major arterial	1	1	5	2.2E-08	7.658
Major arterial	2	2	1	4.4E-08	7.357
Highway/Expressway	4	2	4	8.8E-08	7.056
Major arterial	1	2	5	2.2E-08	7.658
Highway/Expressway	4	3	1	8.8E-08	7.056
Major arterial	2	3	4	4.4E-08	7.357
Major arterial	1	3	6	2.2E-08	7.658
Highway/Expressway	4	4	2	8.8E-08	7.056
Major arterial	2	4	3	4.4E-08	7.357
Major arterial	1	4	6	2.2E-08	7.658
Major arterial	1	5	1	2.2E-08	7.658
Major arterial	1	5	2	2.2E-08	7.658
Freeway	2	5	6	4.4E-08	7.357
Major arterial	1	6	3	2.2E-08	7.658
Major arterial	1	6	4	2.2E-08	7.658
Highway/Expressway	2	6	5	4.4E-08	7.357

The total cost which is summation of log(e) = 133.62. we find that there is slightly difference in the risks among the selected segments based on the calculated log(e). Therefore, selecting any path will provide approximately the same risk; however, selecting the shortest length can provide less risks.

PROBLEM (3) The Transshipment Problem on 6-Node Network

a) The table below shows after modifying under the constrains:

- There are plants (P) with supply s(i) on nodes 1 and 2; s(1) = 3; s(2) = 3;
- There are warehouses (Q) with demand d(j) on nodes 3 and 4; d(3)=4; d(4) = 2;
- The travel time for the trucks is calculated by using 1.25% of the given link costs.
- Include the given link capacity constraints.

link_type_name	length_in_mile	from_node_id	to_node_id	flow	capacity constraint	length_in_mile	link cost	node_id	Fixed demand /supply	Flow Balance
Major arterial	2.5	1	2	0	2	2.5	0.00	1	3	0.00
Highway/Expresswa	5	1	3	3	3	5	15.00	2	3	0.00
Major arterial	1.25	1	5	0	2	1.25	0.00	3	-4	0.00
Major arterial	2.5	2	1	0	2	2.5	0.00	4	-2	0.00
Highway/Expresswa	5	2	4	2	3	5	10.00	5	0	0.00
Major arterial	1.25	2	5	1	2	1.25	1.25	6	0	0.00
Highway/Expresswa	5	3	1	0	3	5	0.00			
Major arterial	2.5	3	4	0	2	2.5	0.00			
Major arterial	1.25	3	6	0	2	1.25	0.00			
Highway/Expresswa	5	4	2	0	3	5	0.00			
Major arterial	2.5	4	3	0	2	2.5	0.00			
Major arterial	1.25	4	6	0	2	1.25	0.00			
Major arterial	1.25	5	1	0	2	1.25	0.00			
Major arterial	1.25	5	2	0	2	1.25	0.00			
Freeway	2.5	5	6	1	6	2.5	2.50			
Major arterial	1.25	6	3	1	2	1.25	1.25			
Major arterial	1.25	6	4	0	2	1.25	0.00			
Highway/Expresswa	2.5	6	5	0	5	2.5	0.00			

B) After solving the problem in excel using the Solver, it shows that the total cost = **30.**

C) As shown below, after change the supply on node 4 is increased to 2.5, it shows that the total cost = **17.5.**

link_type_name	length_in_mile	from_node_id	to_node_id	flow	capacity constraint	length_in_mile	link cost	node_id	Fixed demand /supply	Flow Balance
Major arterial	2.5	1	2	0	2	2.5	0.00	1	3	0.00
Highway/Expresswa	5	1	3	3	3	5	15.00	2	3	-3.00
Major arterial	1.25	1	5	0	2	1.25	0.00	3	-4	0.00
Major arterial	2.5	2	1	0	2	2.5	0.00	4	2.5	-1.50
Highway/Expresswa	5	2	4	0	3	5	0.00	5	0	0.00
Major arterial	1.25	2	5	0	2	1.25	0.00	6	0	0.00
Highway/Expresswa	5	3	1	0	3	5	0.00			
Major arterial	2.5	3	4	0	2	2.5	0.00			
Major arterial	1.25	3	6	0	2	1.25	0.00			
Highway/Expresswa	5	4	2	0	3	5	0.00			
Major arterial	2.5	4	3	1	2	2.5	2.50			
Major arterial	1.25	4	6	0	2	1.25	0.00			
Major arterial	1.25	5	1	0	2	1.25	0.00			
Major arterial	1.25	5	2	0	2	1.25	0.00			
Freeway	2.5	5	6	0	6	2.5	0.00			
Major arterial	1.25	6	3	0	2	1.25	0.00			
Major arterial	1.25	6	4	0	2	1.25	0.00			
Highway/Expresswa	2.5	6	5	0	5	2.5	0.00			

d) Keeping the supply on node 4 = 2, when the capacity on link (1-3) is reduced to 2. And using the solver, it shows that the total cost reduced to (Total cost = 15.).

PROBLEM (4) Optimal Delivery Problem on 6-Node Network

In this problem, we have selected multiple stops within the network which are [(node 1 to 2) and (node 2 to 4), (node 1 to3) and (node 3 to 4)], by changing the values in the flow column to be "1", and then try to solve using the solver. The following table below shows the results which indicates that the total distance = 16

link_type_name	length_in_mile	from_node	to_node_i	flow	freeway link flag	freeway use	length_in_mile	link cost	node_id	Fixed demand	Flow Balance
Major arterial	2	1	2	1	0	0	2	2	1	1	0.00
Highway/Expresswa	4	1	3	1	0	0	4	4	2	0	0.00
Major arterial	1	1	5	0	0	0	1	0	3	0	0.00
Major arterial	2	2	1	0	0	0	2	0	4	-1	0.00
Highway/Expresswa	4	2	4	1	0	0	4	4	5	0	0.00
Major arterial	1	2	5	0	0	0	1	0	6	0	0.00
Highway/Expresswa	4	3	1	0	0	0	4	0			
Major arterial	2	3	4	1	0	0	2	2			
Major arterial	1	3	6	0	0	0	1	0			
Highway/Expresswa	4	4	2	0	0	0	4	0			
Major arterial	2	4	3	0	0	0	2	0			
Major arterial	1	4	6	1	0	0	1	1			
Major arterial	1	5	1	1	0	0	1	1			
Major arterial	1	5	2	0	0	0	1	0			
Freeway	2	5	6	0	1	0	2	0			
Major arterial	1	6	3	0	0	0	1	0			
Major arterial	1	6	4	0	0	0	1	0			
Highway/Expresswa	2	6	5	1	0	0	2	2			
					free-flow usage	0					
							total path distance	16			

We can see from the table above, the path could be (1-2-4-6).

PROBLEM (5) Most Reliable Path on 6-Node Network

Assume the following given inputs:

Let P_{ij} be the probability that a link is working, and that all link are independent.

The probability that a path P is working is product of working probability over all links along a path.

Let P_{ij} = # of lanes/5 for each link

Objective:

The objective is to find the shortest and most reliable path.

$$C(i,j) = \log\left(\frac{1}{P(i,j)}\right)$$

P(i,j) = No. of lanes/5

The table below shows the C(i,j) and number of lanes for each direction:

link_type_name	length_in_mile	from_node_id	to_node_id	No. of lanes	P(i,j)	C(i,j)
Major arterial	**2**	**1**	**2**	**2**	**0.4**	**0.40**
Highway/Expressway	**4**	**1**	**3**	**4**	**0.8**	**0.10**
Major arterial	**1**	**1**	**5**	**1**	**0.2**	**0.70**
Major arterial	**2**	**2**	**1**	**2**	**0.4**	**0.40**
Highway/Expressway	**4**	**2**	**4**	**4**	**0.8**	**0.10**
Major arterial	**1**	**2**	**5**	**1**	**0.2**	**0.70**
Highway/Expressway	**4**	**3**	**1**	**4**	**0.8**	**0.10**
Major arterial	**2**	**3**	**4**	**2**	**0.4**	**0.40**
Major arterial	**1**	**3**	**6**	**1**	**0.2**	**0.70**
Highway/Expressway	**4**	**4**	**2**	**4**	**0.8**	**0.10**
Major arterial	**2**	**4**	**3**	**2**	**0.4**	**0.40**
Major arterial	**1**	**4**	**6**	**1**	**0.2**	**0.70**
Major arterial	**1**	**5**	**1**	**1**	**0.2**	**0.70**
Major arterial	**1**	**5**	**2**	**1**	**0.2**	**0.70**
Freeway	**2**	**5**	**6**	**2**	**0.4**	**0.40**
Major arterial	**1**	**6**	**3**	**1**	**0.2**	**0.70**
Major arterial	**1**	**6**	**4**	**1**	**0.2**	**0.70**
Highway/Expressway	**2**	**6**	**5**	**2**	**0.4**	**0.40**

From the figure above, assume we want to go from node (1) to node (4), we can see that the shortest and most reliable way is **1-3-4** which the cost is the lowest in this selected path. In this path the cost = 0.1+0.4 = **0.50.**

PROBLEM (6) Chinese Postman Problem

Objective:

The objective is to find a path for the patrol vehicle while minimizing the total travel distance.

Requirement:

Modify a min cost flow model to construct an optimization model for the Route Inspection Problem.

Hints:

Min $z=\sum_{ij} c_{ij}\, x_{ij}$
Subject to
$\sum_i x_{ij} - \sum_k x_{jk} = b$

$\mathbf{x_{ij\ j} \geq 1}\ \forall(\mathbf{i}, \mathbf{j}) \in \mathbf{A}$

In this problem, we have to change the flow for all sections to satisfy ($x_{ij\ j} \geq 1\ \forall(\mathbf{i}, \mathbf{j}) \in \mathbf{A}$), and then run the solver. The table below shows the results after running the solver.

link_type_name	length_in_mile	from_node	to_node_i	flow	freeway link flag	freway use variable	length_in_mile	link cost	node_id	Fixed demand	Flow Balance
Major arterial	2	1	2	2	0	0	2	4	1	1	0.00
Highway/Expresswa	4	1	3	1	0	0	4	4	2	0	0.00
Major arterial	1	1	5	1	0	0	1	1	3	0	0.00
Major arterial	2	2	1	1	0	0	2	2	4	-1	0.00
Highway/Expresswa	4	2	4	2	0	0	4	8	5	0	0.00
Major arterial	1	2	5	1	0	0	1	1	6	0	0.00
Highway/Expresswa	4	3	1	1	0	0	4	4			
Major arterial	2	3	4	1	0	0	2	2			
Major arterial	1	3	6	1	0	0	1	1			
Highway/Expresswa	4	4	2	1	0	0	4	4			
Major arterial	2	4	3	1	0	0	2	2			
Major arterial	1	4	6	1	0	0	1	1			
Major arterial	1	5	1	1	0	0	1	1			
Major arterial	1	5	2	1	0	0	1	1			
Freeway	2	5	6	1	1	1	2	2			
Major arterial	1	6	3	1	0	0	1	1			
Major arterial	1	6	4	1	0	0	1	1			
Highway/Expresswa	2	6	5	1	0	0	2	2			

-The results indicate that the total cost = 42.

-also, from the results, path for the patrol vehicle while minimizing the total travel distance is (1-2), (2,4).

Problem 7:

- In this problem the Chicago Network was considered to find the shortest path and the optimum solution. The following website was considered to solve this problem: https://www.strandmark.net/wasm/glpk.html.

- From the Chicago network, we found that the Chicago posses 933 nodes

The following answer obtained for short path coding after running the coding

```
Scaling...
 A: min|aij| =  1.000e+00  max|aij| =  1.000e+00  ratio =  1.000e+00
Problem data seem to be well scaled
Constructing initial basis...
Size of triangular part is 6
      0: obj =  -1.000000000e+02 inf =   1.000e+00 (1)
      1: obj =   2.000000000e+01 inf =   0.000e+00 (0)
*     2: obj =   2.000000000e+01 inf =   0.000e+00 (0)
OPTIMAL LP SOLUTION FOUND
```

Also, the following answer obtained for Max Flow coding after running the coding

```
Scaling...
 A: min|aij| =  1.000e+00  max|aij| =  1.000e+00  ratio =  1.000e+00
Problem data seem to be well scaled
Constructing initial basis...
Size of triangular part is 6
      0: obj =   0.000000000e+00 inf =   1.000e+00 (1)
      1: obj =   2.000000000e+01 inf =   0.000e+00 (0)
*     2: obj =   2.000000000e+01 inf =   0.000e+00 (0)
OPTIMAL LP SOLUTION FOUND
```