Exam_2 Q1

Contents

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Q2

```
clear, close all
df = table2struct(readtable('Exam2DataF20.xlsx'));

XY = [[df.Longitude]' [df.Latitude]'];
q = [df(2:end).Weight]'/2000;
s = [df(2:end).Density]';
tL = 20/60;
tU = 5/60;

sh = vec2struct('b',1,'e',[df(2:end).Customer]', 'q', q, 's', s);
tr = struct('b',1,'e',1,'tbmin',7,'temax',17,'Kwt',25,'Kcu',2750,...
    'maxTC', 10);

i = find([sh.q]'*2000./[sh.s]'/tr.Kcu > 1) % which shipment is above truck cubic capacity
srpls = sh(i).q*2000/sh(i).s/tr.Kcu - 1 % fraction of the surpluss

sh(end+1) = sh(i); % add additional shipment
sh(end).q = srpls*sh(i).q;

sh(i).q = sh(i).q - sh(end).q; % subtract additional shipment from overcubic shipment

sh = vec2struct(sh,'tU',[sh.q]'*tU, 'temin',7,'temax',17);
sdisp(sh)
```

```
i =
    28
srpls =
    0.0160
```

sh:	b	e	q	s	tU	temin	temax
1:	1	2	1.53	6.39	0.1276	7	17
2:	1	3	1.22	18.06	0.1018	7	17
3:	1	4	1.47	12.64	0.1225	7	17
4:	1	5	2.07	18.53	0.1722	7	17
5:	1	6	1.26	7.77	0.1053	7	17
6:	1	7	1.26	2.65	0.1047	7	17
7:	1	8	1.98	13.32	0.1652	7	17
8:	1	9	1.22	2.70	0.1020	7	17
9:	1	10	1.61	6.68	0.1340	7	17
10:	1	11	1.24	5.59	0.1034	7	17
11:	1	12	1.75	4.68	0.1458	7	17
12:	1	13	1.26	3.48	0.1050	7	17
13:	1	14	2.16	3.41	0.1798	7	17
14:	1	15	2.09	8.37	0.1743	7	17
15:	1	16	1.38	12.83	0.1152	7	17
16:	1	17	1.40	7.18	0.1169	7	17
17:	1	18	1.75	3.88	0.1459	7	17
18:	1	19	1.86	2.18	0.1548	7	17
19:	1	20	1.12	5.70	0.0935	7	17
20:	1	21	2.02	20.14	0.1681	7	17
21:	1	22	1.79	11.94	0.1489	7	17
22:	1	23	1.22	14.27	0.1019	7	17
23:	1	24	1.37	1.60	0.1144	7	17
24:	1	25	1.33	9.47	0.1111	7	17
25:	1	26	1.51	17.86	0.1260	7	17
26:	1	27	2.70	5.93	0.2253	7	17
27:	1	28	1.37	9.37	0.1139	7	17
28:	1	29	1.61	1.17	0.1340	7	17
29:	1	30	1.45	4.23	0.1210	7	17
30:	1	31	2.22	10.49	0.1852	7	17
31:	1	32	1.32	8.69	0.1097	7	17
32:	1	33	1.25	10.32	0.1042	7	17
33:	1	34	1.26	2.37	0.1050	7	17
34:	1	35	1.49	5.35	0.1240	7	17
35:	1	36	1.87	5.54	0.1558	7	17
36:	1	37	1.47	7.37	0.1229	7	17
37:	1	38	1.63	10.77	0.1357	7	17
38:	1	39	1.25	10.91	0.1043	7	17
39:	1	40	1.62	4.33	0.1347	7	17
40:	1	41	1.33	10.06	0.1107	7	17
41:	1	42	1.34	7.35	0.1118	7	17
42:	1	43	1.73	8.23	0.1441	7	17
43:	1	44	1.63	24.33	0.1358	7	17
44:	1	45	1.39	8.40	0.1158	7	17
45:	1	46	2.38	21.38	0.1981	7	17
46:	1	29	0.03	1.17	0.0022	7	17

Get road network

```
expansionAroundXY = 0.1;
[XY2,IJD,isXY,isIJD] = subgraph(usrdnode('XY'),...
```

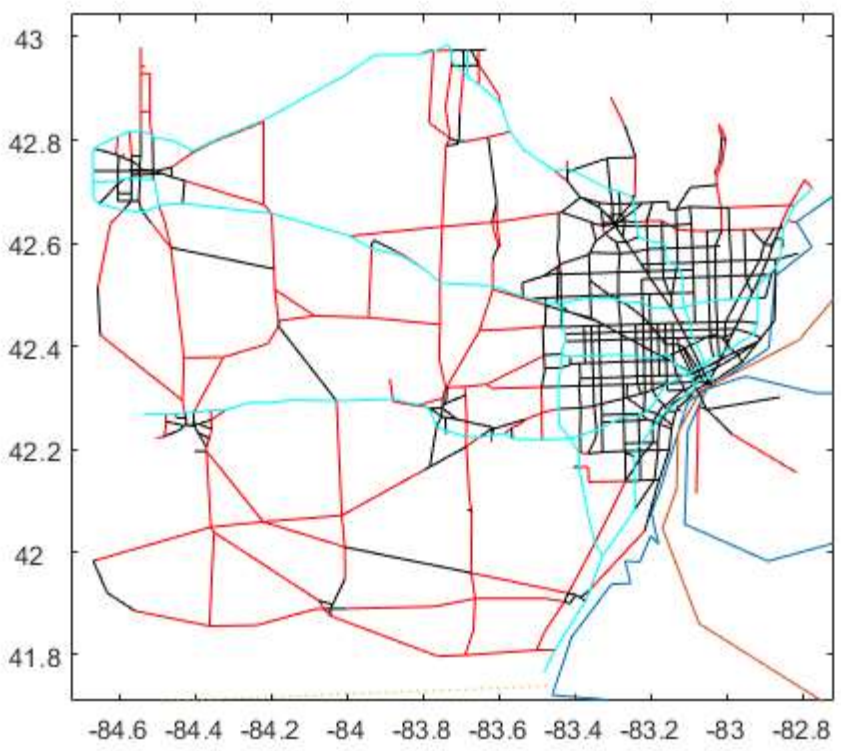
```
    isinrect(usrdnode('XY'),boundrect(XY,expansionAroundXY)),...
    usrdlink('IJD'));
```

Label type of road

```
s = usrdlink(isIJD);
isI = s.Type == 'I';         % Interstate highways
isIR = isI & s.Urban == ' '; % Rural Interstate highways
isIU = isI & ~isIR;          % Urban Interstate highways
isR = s.Urban == ' ' & ~isI; % Rural non-Interstate roads
isU = ~isI & ~isR;           % Urban non-Interstate roads
```

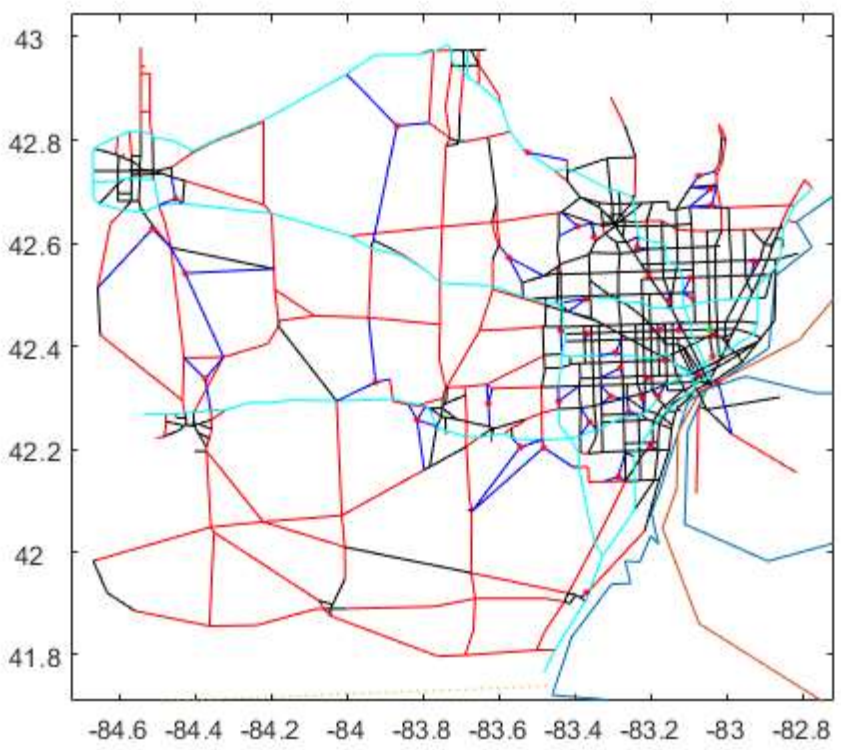
Plot roads

```
makemap(XY2,0.03)  % 3% expansion
h = [];  % Keep handle to each plot for legend
h = [h pplot(IJD(isR,:),XY2,'r-','DisplayName','Rural Roads')];
h = [h pplot(IJD(isU,:),XY2,'k-','DisplayName','Urban Roads')];
h = [h pplot(IJD(isI,:),XY2,'c-','DisplayName','Interstate Roads')];
```



Add connector roads from customers to road network

```
[IJD11,IJD12,IJD22] = addconnector(XY,XY2,IJD);
h = [h pplot(IJD12,[XY; XY2],'b-','DisplayName','Connector Roads')];
h = [h pplot(XY(2:end,:),'r.','DisplayName','Customers')];
h = [h pplot(XY(1,:),'g.','DisplayName','DC')];
```



Convert road distances to travel times (needs to be after ADDCONNECTOR)

```
v.IR = 75;  % Rural Interstate highways average speed (mph)
v.IU = 65;  % Urban Interstate highways average speed (mph)
v.R = 50;   % Rural non-Interstate roads average speed (mph)
v.U = 25;   % Urban non-Interstate roads average speed (mph)
v.C = 20;   % Facility to road connector average speed (mph)

IJT = IJD;
IJT(isIR,3) = IJD(isIR,3)/v.IR;
IJT(isIU,3) = IJD(isIU,3)/v.IU;
IJT(isR,3) = IJD(isR,3)/v.R;
IJT(isU,3) = IJD(isU,3)/v.U;

IJT22 = IJD22;                % road to road
IJT22(:,3) = IJT(:,3);
IJT12 = IJD12;                % facility to road
IJT12(:,3) = IJD12(:,3)/v.C;  % (IJD11 facility to facility arcs ignored)
```

Shortest time routes

```
n = size(XY,1);
[T,P] = dijk(list2adj([IJT12; IJT22]),1:n,1:n);
T = T+5/60;
```

Construct & improve routes:

```
rTCh = @(rte) rteTC(rte,sh,T,tr);
tic
IJS = pairwisesavings(rTCh,sh); toc
```

```
tic
r = twoopt(savings(rTCh,sh,IJS),rTCh); toc
```

```
Elapsed time is 4.575187 seconds.
Elapsed time is 5.265845 seconds.
```

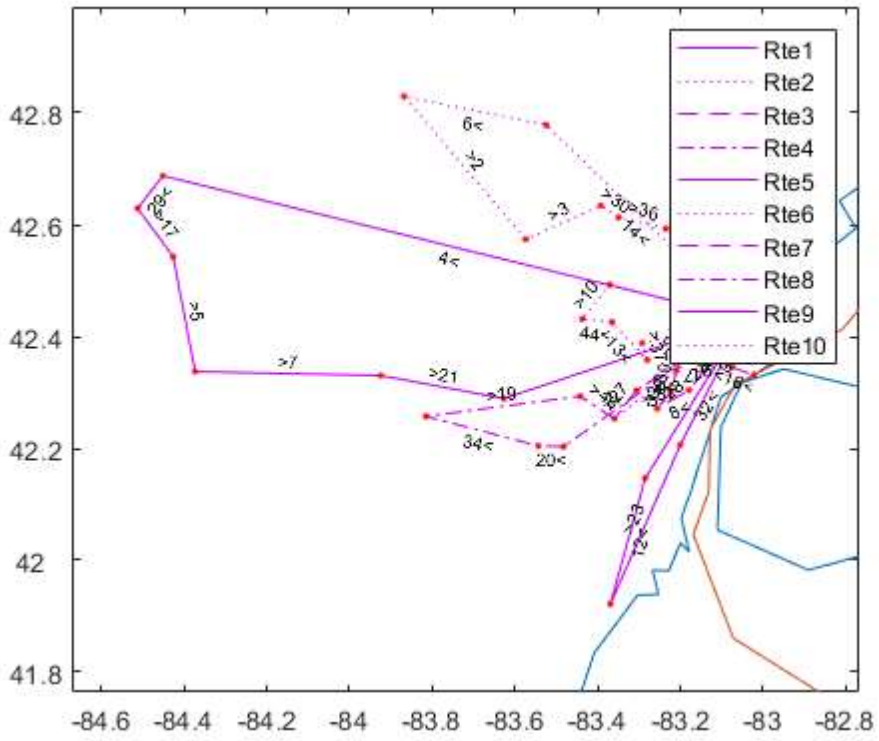
add any single-shipment routes

```
[r,~,Time] = sh2rte(sh,r,rTCh);
```

```
ADD SINGLE-SHIPMENT ROUTES:
34.487040: Added shipments 18 28
```

Plot routes

```
plotshmt(sh,XY,r,tr)
```



Display route output structure

```
[TC,Xflg,out] = rTCh(r);
for i = 1:length(out), sdisp(out(i),false,i), end
```

```
  1:  Rte  Loc  Cost  Arrive  Wait  TWmin  Start    LU    Depart  TWmax  Total
```

	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.00	0.00	0	7	7.00	0.0000	7.00	Inf	0.00
2:	21	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
3:	7	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
4:	5	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
5:	4	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
6:	29	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
7:	17	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
8:	4	5	1.33	8.33	0	7	8.33	0.1722	8.50	17	1.50
9:	29	30	0.42	8.92	0	7	8.92	0.1210	9.04	17	0.54
10:	17	18	0.52	9.56	0	7	9.56	0.1459	9.71	17	0.67
11:	5	6	0.98	10.69	0	7	10.69	0.1053	10.80	17	1.09
12:	7	8	0.94	11.73	0	7	11.73	0.1652	11.90	17	1.10
13:	21	22	0.72	12.62	0	7	12.62	0.1489	12.77	17	0.87
14:	0	1	1.03	13.80	0	-Inf	13.80	0.0000	13.80	17	1.03

	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.00	0.00	0	7	7.00	0.0000	7.00	Inf	0.00
2:	36	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
3:	3	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
4:	30	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
5:	2	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
6:	14	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
7:	6	1	0.00	7.00	0	7	7.00	0.0000	7.00	Inf	0.00
8:	14	15	0.82	7.82	0	7	7.82	0.1743	8.00	17	1.00
9:	6	7	0.80	8.80	0	7	8.80	0.1047	8.90	17	0.91
10:	2	3	1.09	10.00	0	7	10.00	0.1018	10.10	17	1.19
11:	3	4	0.70	10.80	0	7	10.80	0.1225	10.92	17	0.82
12:	30	31	0.36	11.28	0	7	11.28	0.1852	11.47	17	0.55
13:	36	37	0.45	11.91	0	7	11.91	0.1229	12.04	17	0.57
14:	0	1	0.57	12.60	0	-Inf	12.60	0.0000	12.60	17	0.57

	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.0000	0.00	0	7	7.00	0.0000	7.00	Inf	0.0000
2:	1	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
3:	25	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
4:	45	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
5:	40	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
6:	41	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
7:	26	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
8:	22	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
9:	43	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
10:	41	42	0.5888	7.59	0	7	7.59	0.1118	7.70	17	0.7005
11:	26	27	0.5516	8.25	0	7	8.25	0.2253	8.48	17	0.7769
12:	22	23	0.3114	8.79	0	7	8.79	0.1019	8.89	17	0.4133
13:	43	44	0.3586	9.25	0	7	9.25	0.1358	9.39	17	0.4945
14:	45	46	0.7890	10.17	0	7	10.17	0.1981	10.37	17	0.9871
15:	1	2	0.2578	10.63	0	7	10.63	0.1276	10.76	17	0.3854
16:	40	41	0.4116	11.17	0	7	11.17	0.1107	11.28	17	0.5224
17:	25	26	0.3225	11.60	0	7	11.60	0.1260	11.73	17	0.4485
18:	0	1	0.3572	12.09	0	-Inf	12.09	0.0000	12.09	17	0.3572

	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.0000	0.00	0	7	7.00	0.0000	7.00	Inf	0.0000
2:	27	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
3:	46	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
4:	19	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
5:	33	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000

6:	34	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
7:	20	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
8:	33	34	0.7256	7.73	0	7	7.73	0.1050	7.83	17	0.8305
9:	20	21	0.3326	8.16	0	7	8.16	0.1681	8.33	17	0.5007
10:	34	35	0.5569	8.89	0	7	8.89	0.1240	9.01	17	0.6809
11:	19	20	0.6639	9.68	0	7	9.68	0.0935	9.77	17	0.7574
12:	46	29	0.3973	10.17	0	7	10.17	0.0022	10.17	17	0.3995
13:	27	28	0.4514	10.62	0	7	10.62	0.1139	10.73	17	0.5653
14:	0	1	0.7024	11.44	0	-Inf	11.44	0.0000	11.44	17	0.7024

5:	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.0000	0.00	0	7	7.00	0.0000	7.00	Inf	0.0000
2:	23	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
3:	32	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
4:	12	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
5:	32	33	0.7153	7.72	0	7	7.72	0.1042	7.82	17	0.8195
6:	12	13	0.4951	8.31	0	7	8.31	0.1050	8.42	17	0.6001
7:	23	24	0.5409	8.96	0	7	8.96	0.1144	9.07	17	0.6553
8:	0	1	0.5744	9.65	0	-Inf	9.65	0.0000	9.65	17	0.5744

6:	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.0000	0.00	0	7	7.00	0.0000	7.00	Inf	0.0000
2:	10	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
3:	15	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
4:	37	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
5:	44	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
6:	13	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
7:	15	16	0.5184	7.52	0	7	7.52	0.1152	7.63	17	0.6336
8:	37	38	0.2515	7.89	0	7	7.89	0.1357	8.02	17	0.3873
9:	13	14	0.4055	8.43	0	7	8.43	0.1798	8.61	17	0.5853
10:	44	45	0.2804	8.89	0	7	8.89	0.1158	9.00	17	0.3962
11:	10	11	0.2803	9.28	0	7	9.28	0.1034	9.39	17	0.3837
12:	0	1	0.4965	9.88	0	-Inf	9.88	0.0000	9.88	17	0.4965

7:	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.0000	0.00	0	7	7.00	0.0000	7.00	Inf	0.0000
2:	24	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
3:	8	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
4:	9	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
5:	39	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
6:	38	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
7:	9	10	0.4134	7.41	0	7	7.41	0.1340	7.55	17	0.5474
8:	8	9	0.2759	7.82	0	7	7.82	0.1020	7.93	17	0.3780
9:	38	39	0.3531	8.28	0	7	8.28	0.1043	8.38	17	0.4573
10:	39	40	0.2575	8.64	0	7	8.64	0.1347	8.77	17	0.3921
11:	24	25	0.4093	9.18	0	7	9.18	0.1111	9.30	17	0.5204
12:	0	1	0.3856	9.68	0	-Inf	9.68	0.0000	9.68	17	0.3856

8:	Rte	Loc	Cost	Arrive	Wait	TWmin	Start	LU	Depart	TWmax	Total
1:	0	1	0.0000	0.00	0	7	7.00	0.0000	7.00	Inf	0.0000
2:	11	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
3:	42	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
4:	31	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
5:	35	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
6:	16	1	0.0000	7.00	0	7	7.00	0.0000	7.00	Inf	0.0000
7:	11	12	0.1463	7.15	0	7	7.15	0.1458	7.29	17	0.2921
8:	31	32	0.3417	7.63	0	7	7.63	0.1097	7.74	17	0.4513

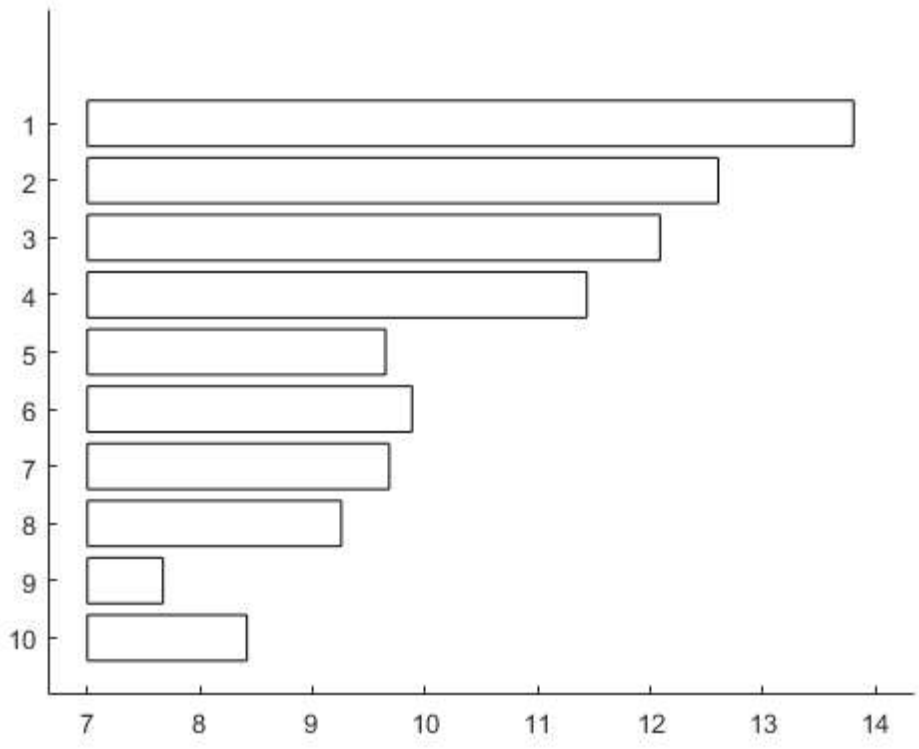
```
 9:   16   17  0.2346   7.98     0       7   7.98  0.1169   8.09     17   0.3516
10:   35   36  0.2426   8.34     0       7   8.34  0.1558   8.49     17   0.3984
11:   42   43  0.3426   8.84     0       7   8.84  0.1441   8.98     17   0.4868
12:    0    1  0.2747   9.25     0    -Inf   9.25  0.0000   9.25     17   0.2747
```

```
9:  Rte  Loc   Cost   Arrive  Wait  TWmin  Start    LU    Depart  TWmax   Total
-:----------------------------------------------------------------------------
1:    0    1  0.0000   0.00     0       7   7.00  0.0000   7.00    Inf   0.0000
2:   18    1  0.0000   7.00     0       7   7.00  0.0000   7.00    Inf   0.0000
3:   18   19  0.2587   7.26     0       7   7.26  0.1548   7.41     17   0.4135
4:    0    1  0.2587   7.67     0    -Inf   7.67  0.0000   7.67     17   0.2587
```

```
10:  Rte  Loc   Cost   Arrive  Wait  TWmin  Start    LU    Depart  TWmax   Total
--:----------------------------------------------------------------------------
 1:    0    1  0.0000   0.00     0       7   7.00  0.0000   7.00    Inf   0.0000
 2:   28    1  0.0000   7.00     0       7   7.00  0.0000   7.00    Inf   0.0000
 3:   28   29  0.6417   7.64     0       7   7.64  0.1340   7.78     17   0.7757
 4:    0    1  0.6417   8.42     0    -Inf   8.42  0.0000   8.42     17   0.6417
```

Display Gantt chort of route spans

```
b= arrayfun(@(x) (x.Start(1)),out); b = b(:);
e= arrayfun(@(x) (x.Depart(end)),out); e = e(:);
figure
gantt([b e])
```



Route time and delivery cubic ft

```
for i = 1:length(r)
    idx = r{i}(isorigin(r{i}));
    Maxload(i) = sum([sh(idx).q]'*2000./[sh(idx).s]');
```

```
end
vdisp('Time, Maxload')
```

```
  :  Time   Maxload
--:----------------
 1:  6.80  2,734.53
 2:  5.60  2,639.77
 3:  5.09  2,717.57
 4:  4.44  2,549.38
 5:  2.65  2,682.73
 6:  2.88  2,558.49
 7:  2.68  2,645.69
 8:  2.25  2,536.57
 9:  0.67  1,704.13
10:  1.42  2,749.30
```

number of trucks

```
m = length(Time);
M = 1:m;
V = 10;
v = Time;
mp = Milp('# of Trucks');
mp.addobj('min',ones(1,m),zeros(m));
for i = M
   mp.addcstr({V,{i}},'>=',{v+tL,{i,':'}})   % V*yi >= sum_j(vj*xij)
end
for j = M
   mp.addcstr(0,{':',j},'=',1)            % sum_i(xij) = 1
end
mp.addctype('B','B')
```

Use INTLINPROG to solve

```
ilp = mp.milp2ilp;
x = intlinprog(ilp{:});
x = mp.namesolution(x);
B = arrayfun(@(i) find(x.arg2(i,:)),find(x.arg1),'UniformOutput',false);
B{:}
fprintf('Number of required trucks is %d.\n', length(B))
```

```
LP:                Optimal objective value is 3.782037.

Cut Generation:    Applied 1 clique cut, 2 cover cuts,
                   and 2 mir cuts.
                   Lower bound is 4.000000.

Heuristics:        Found 1 solution using ZI round.
                   Upper bound is 5.000000.
                   Relative gap is 16.67%.

Cut Generation:    Applied 4 clique cuts.
                   Lower bound is 4.000000.
                   Relative gap is 16.67%.
```

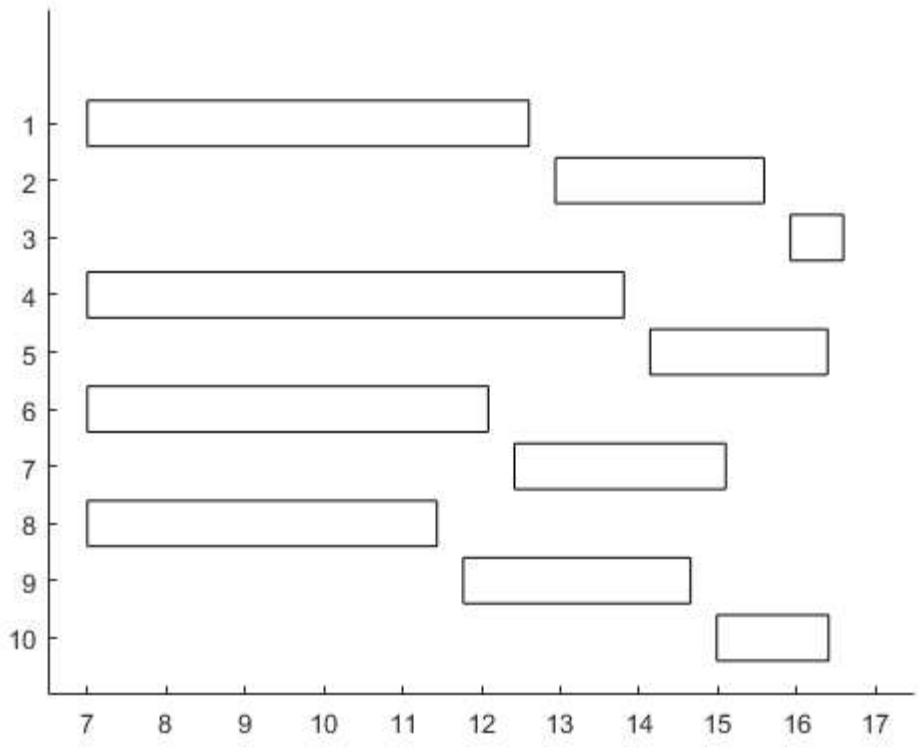
```
Branch and Bound:

   nodes     total   num int        integer       relative
explored  time (s)  solution           fval        gap (%)
      34      0.04         2   4.000000e+00   2.980232e-06

Optimal solution found.

Intlinprog stopped because the objective value is within a gap tolerance of the
optimal value, options.AbsoluteGapTolerance = 0 (the default value). The intcon
variables are integer within tolerance, options.IntegerTolerance = 1e-05 (the
default value).

ans =
     2     5     9
ans =
     1     8
ans =
     3     7
ans =
     4     6    10
Number of required trucks is 4.
```

Chart for Trucks;

```
b=[]
for i=1:length(B)
    b = [b; 7 7+Time(B{i}(1))]
    for j=2:length(B{i})
        b = [b; b(end)+tL b(end)+tL+Time(B{i}(j))]
    end
end
figure
gantt([b])
```

```
b =
     []
b =
    7.0000   12.6032
b =
    7.0000   12.6032
   12.9366   15.5859
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
   14.1377   16.3926
```

```
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
   14.1377   16.3926
    7.0000   12.0857
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
   14.1377   16.3926
    7.0000   12.0857
   12.4191   15.0998
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
   14.1377   16.3926
    7.0000   12.0857
   12.4191   15.0998
    7.0000   11.4367
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
   14.1377   16.3926
    7.0000   12.0857
   12.4191   15.0998
    7.0000   11.4367
   11.7700   14.6526
b =
    7.0000   12.6032
   12.9366   15.5859
   15.9192   16.5914
    7.0000   13.8044
   14.1377   16.3926
    7.0000   12.0857
   12.4191   15.0998
    7.0000   11.4367
   11.7700   14.6526
   14.9859   16.4033
```



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