Please study GAMS and check the sample codes at

1. Transportation problem: <https://github.com/xzhou99/learning-transportation/tree/master/GAMS_code%20-space-time-network/0%20transportation>
2. Shortest path problem: <https://github.com/xzhou99/learning-transportation/tree/master/GAMS_code%20-space-time-network/1%20shortest_path>

and provide the GAMS codes and solution output for the following problems.

**1. Transportation problem:**

Cities 1 and 2 have 100K and 200K passengers per year, respectively. Airports 1 and 2 can accept a demand of 150K passengers per year each. The city-to-airport driving times are listed below.

|  |  |  |
| --- | --- | --- |
| Origin (City) | Destination (Airport) | Time (minutes) |
| 1 | 1 | 30 |
| 1 | 2 | 60 |
| 2 | 1 | 50 |
| 2 | 2 | 45 |

Please formulate the linear programming problem and solve it using GAMS Solver.

Reading. [http://web.mit.edu/15.053/www/AMP-Chapter-08.pdf section 8.2](http://web.mit.edu/15.053/www/AMP-Chapter-08.pdf%20section%208.2)

Given:

: the demand of city ,

: the capacity of airport ,

: the driving time from city to airport

To find:

: the passengers traveling from city to airport

: the total travel cost

Model:

Subject to

Solution from GAMS in thousands of passengers:

GAMS Input Code

|  |
| --- |
| Transportation problem  Set i /1\*2/;  alias (i, j);  parameter a(i)/  1 100  2 200  /;  parameter b(j)/  1 150  2 150  /;  parameter c(i,j)/  1. 1 30  1. 2 60  2. 1 50  2. 2 45  /;  variable z;  positive variables x(i,j);  equations  obj  demand(i)  supply(j)  ;  obj.. z =e= sum((i,j),c(i,j)\*x(i,j));  demand(i).. sum(j,x(i,j)) =e= a(i);  supply(j).. sum(i,x(i,j)) =e= b(j);  Model problem\_2 /all/;  solve problem\_2 using LP minimizing z;  display x.l;  display z.l; |

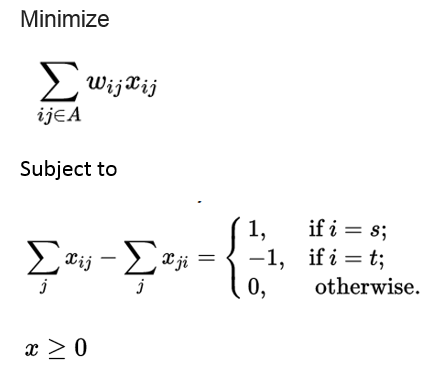
GAMS Output Code

|  |
| --- |
| GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:47:34 Page 1  Transportation problem  C o m p i l a t i o n  2  3 Set i /1\*2/;  4 alias (i, j);  5  6 parameter a(i)/  7 1 100  8 2 200  9 /;  10  11 parameter b(j)/  12 1 150  13 2 150  14 /;  15  16 parameter c(i,j)/  17 1. 1 30  18 1. 2 60  19 2. 1 50  20 2. 2 45  21 /;  22  23 variable z;  24 positive variables x(i,j);  25  26 equations  27 obj  28 demand(i)  29 supply(j)  30 ;  31  32 obj.. z =e= sum((i,j),c(i,j)\*x(i,j));  33 demand(i).. sum(j,x(i,j)) =e= a(i);  34 supply(j).. sum(i,x(i,j)) =e= b(j);  35  36 Model problem\_2 /all/;  37 solve problem\_2 using LP minimizing z;  38  39 display x.l;  40 display z.l;  COMPILATION TIME = 0.015 SECONDS 3 MB 32.2.0 rc62c018 WEX-WEI  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:47:34 Page 2  Transportation problem  Equation Listing SOLVE problem\_2 Using LP From line 37  ---- obj =E=  obj.. z - 30\*x(1,1) - 60\*x(1,2) - 50\*x(2,1) - 45\*x(2,2) =E= 0 ; (LHS = 0)    ---- demand =E=  demand(1).. x(1,1) + x(1,2) =E= 100 ; (LHS = 0, INFES = 100 \*\*\*\*)    demand(2).. x(2,1) + x(2,2) =E= 200 ; (LHS = 0, INFES = 200 \*\*\*\*)    ---- supply =E=  supply(1).. x(1,1) + x(2,1) =E= 150 ; (LHS = 0, INFES = 150 \*\*\*\*)    supply(2).. x(1,2) + x(2,2) =E= 150 ; (LHS = 0, INFES = 150 \*\*\*\*)    GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:47:34 Page 3  Transportation problem  Column Listing SOLVE problem\_2 Using LP From line 37  ---- z  z  (.LO, .L, .UP, .M = -INF, 0, +INF, 0)  1 obj  ---- x  x(1,1)  (.LO, .L, .UP, .M = 0, 0, +INF, 0)  -30 obj  1 demand(1)  1 supply(1)  x(1,2)  (.LO, .L, .UP, .M = 0, 0, +INF, 0)  -60 obj  1 demand(1)  1 supply(2)  x(2,1)  (.LO, .L, .UP, .M = 0, 0, +INF, 0)  -50 obj  1 demand(2)  1 supply(1)  REMAINING ENTRY SKIPPED  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:47:34 Page 4  Transportation problem  Model Statistics SOLVE problem\_2 Using LP From line 37  MODEL STATISTICS  BLOCKS OF EQUATIONS 3 SINGLE EQUATIONS 5  BLOCKS OF VARIABLES 2 SINGLE VARIABLES 5  NON ZERO ELEMENTS 13  GENERATION TIME = 0.079 SECONDS 4 MB 32.2.0 rc62c018 WEX-WEI  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:47:34 Page 5  Transportation problem  Solution Report SOLVE problem\_2 Using LP From line 37  S O L V E S U M M A R Y  MODEL problem\_2 OBJECTIVE z  TYPE LP DIRECTION MINIMIZE  SOLVER CPLEX FROM LINE 37  \*\*\*\* SOLVER STATUS 1 Normal Completion  \*\*\*\* MODEL STATUS 1 Optimal  \*\*\*\* OBJECTIVE VALUE 12250.0000  RESOURCE USAGE, LIMIT 0.031 10000000000.000  ITERATION COUNT, LIMIT 0 2147483647  IBM ILOG CPLEX 32.2.0 rc62c018 Released Aug 26, 2020 WEI x86 64bit/MS Window  \*\*\* This solver runs with a demo license. No commercial use.  Cplex 12.10.0.0  Space for names approximately 0.00 Mb  Use option 'names no' to turn use of names off  LP status(1): optimal  Cplex Time: 0.02sec (det. 0.00 ticks)  Optimal solution found.  Objective : 12250.000000  LOWER LEVEL UPPER MARGINAL  ---- EQU obj . . . 1.000  ---- EQU demand  LOWER LEVEL UPPER MARGINAL  1 100.000 100.000 100.000 25.000  2 200.000 200.000 200.000 45.000  ---- EQU supply  LOWER LEVEL UPPER MARGINAL  1 150.000 150.000 150.000 5.000  2 150.000 150.000 150.000 .  LOWER LEVEL UPPER MARGINAL  ---- VAR z -INF 12250.000 +INF .  ---- VAR x  LOWER LEVEL UPPER MARGINAL  1.1 . 100.000 +INF .  1.2 . . +INF 35.000  2.1 . 50.000 +INF .  2.2 . 150.000 +INF .  \*\*\*\* REPORT SUMMARY : 0 NONOPT  0 INFEASIBLE  0 UNBOUNDED  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:47:34 Page 6  Transportation problem  E x e c u t i o n  ---- 39 VARIABLE x.L  1 2  1 100.000  2 50.000 150.000  ---- 40 VARIABLE z.L = 12250.000  EXECUTION TIME = 0.172 SECONDS 4 MB 32.2.0 rc62c018 WEX-WEI  USER: GAMS Demo license for Dr. Zhou G200810|0002CO-GEN  Arizona State Univeristy, United States of America DL014724  \*\*\*\* FILE SUMMARY  Input C:\Users\Adam Tran\Documents\CEE598 \_TrafficSimulation\gams\_codes\1\_T  ransportation problem.gms  Output C:\Users\Adam Tran\Documents\gamsdir\projdir\1\_Transportation problem  .lst |

1. **Shortest path problem**

(you can assume the link length as 1 as a default value and try different values as a sensitivity test)

Reading. [http://web.mit.edu/15.053/www/AMP-Chapter-08.pdf section 8.2](http://web.mit.edu/15.053/www/AMP-Chapter-08.pdf%20section%208.2)

|  |  |  |
| --- | --- | --- |
| Start Node | End Node | Link Length |
| 1 | 2 | 1 |
| 1 | 3 | 1 |
| 2 | 4 | 1 |
| 3 | 4 | 1 |
| 3 | 2 | 1 |

Going from node 1 to 4.

Solution from GAMS:

If the link length from node 1 to node 2 is 2 instead of 1 the solution from GAMS becomes:

If the link length from node 1 to node 2 is 2, and node 3 to 4 is 2, the solution from GAMS becomes:

GAMS Input Code

|  |
| --- |
| $title Shortest Path Problem  \*LIMROW = 0, LIMCOL = 0  \*OPTIONS ITERLIM=100000, RESLIM = 1000000, SYSOUT = OFF, SOLPRINT = OFF, lp = COINGLPK, mip = COINGLPK, OPTCR= 0.1;  set i nodes /1\*4/;  alias (i, j);  parameter w(i,j) link travel time /  1. 2 1  1. 3 1  2. 4 1  3. 4 1  3. 2 1  /;  parameter origin(i);  origin('1') = 1;  parameter destination(i);  destination('4') = 4;  parameter intermediate\_node(i);  intermediate\_node(i) = (1- origin(i))\*(1- destination(i));  variable z;  positive variables  x(i,j) selection of flow between i and j;  equations  so\_obj define objective function  flow\_on\_node\_origin  flow\_on\_node\_intermediate(i)  flow\_on\_node\_destination  ;  so\_obj.. z =e= sum((i,j)$(w(i,j)),w(i,j)\*x(i,j));  flow\_on\_node\_origin.. sum(j$(w('1',j)), x('1',j)) =e= 1;  flow\_on\_node\_intermediate(i)$(intermediate\_node(i)=1).. sum(j$(w(i,j)), x(i,j))-sum(j$(w(j,i)), x(j,i))=e= 0;  flow\_on\_node\_destination.. sum(j$(w(j,'4')), x(j,'4'))=e= 1;  Model shortest\_path\_problem /all/ ;  solve shortest\_path\_problem using LP minimizing z;  display x.l;  display z.l; |

GAMS Output Code

|  |
| --- |
| GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:55:18 Page 1  Shortest Path Problem  C o m p i l a t i o n  2 \*LIMROW = 0, LIMCOL = 0  3 \*OPTIONS ITERLIM=100000, RESLIM = 1000000, SYSOUT = OFF, SOLPRINT = OFF,  lp = COINGLPK, mip = COINGLPK, OPTCR= 0.1;  4  5 set i nodes /1\*4/;  6 alias (i, j);  7  8 parameter w(i,j) link travel time /  9 1. 2 1  10 1. 3 1  11 2. 4 1  12 3. 4 1  13 3. 2 1  14 /;  15  16 parameter origin(i);  17 origin('1') = 1;  18  19 parameter destination(i);  20 destination('4') = 4;  21  22 parameter intermediate\_node(i);  23 intermediate\_node(i) = (1- origin(i))\*(1- destination(i));  24  25 variable z;  26 positive variables  27 x(i,j) selection of flow between i and j;  28  29 equations  30 so\_obj define objective function  31 flow\_on\_node\_origin  32 flow\_on\_node\_intermediate(i)  33 flow\_on\_node\_destination  34 ;  35  36 so\_obj.. z =e= sum((i,j)$(w(i,j)),w(i,j)\*x(i,j));  37 flow\_on\_node\_origin.. sum(j$(w('1',j)), x('1',j)) =e= 1;  38 flow\_on\_node\_intermediate(i)$(intermediate\_node(i)=1).. sum(j$(w(i,j)), x(  i,j))-sum(j$(w(j,i)), x(j,i))=e= 0;  39 flow\_on\_node\_destination.. sum(j$(w(j,'4')), x(j,'4'))=e= 1;  40  41 Model shortest\_path\_problem /all/ ;  42  43 solve shortest\_path\_problem using LP minimizing z;  44  45 display x.l;  46 display z.l;  47  COMPILATION TIME = 0.093 SECONDS 3 MB 32.2.0 rc62c018 WEX-WEI  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:55:18 Page 2  Shortest Path Problem  Equation Listing SOLVE shortest\_path\_problem Using LP From line 43  ---- so\_obj =E= define objective function  so\_obj.. z - x(1,2) - x(1,3) - x(2,4) - x(3,2) - x(3,4) =E= 0 ; (LHS = 0)    ---- flow\_on\_node\_origin =E=  flow\_on\_node\_origin.. x(1,2) + x(1,3) =E= 1 ; (LHS = 0, INFES = 1 \*\*\*\*)    ---- flow\_on\_node\_intermediate =E=  flow\_on\_node\_intermediate(2).. - x(1,2) + x(2,4) - x(3,2) =E= 0 ; (LHS = 0)    flow\_on\_node\_intermediate(3).. - x(1,3) + x(3,2) + x(3,4) =E= 0 ; (LHS = 0)    ---- flow\_on\_node\_destination =E=  flow\_on\_node\_destination.. x(2,4) + x(3,4) =E= 1 ; (LHS = 0, INFES = 1 \*\*\*\*)    GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:55:18 Page 3  Shortest Path Problem  Column Listing SOLVE shortest\_path\_problem Using LP From line 43  ---- z  z  (.LO, .L, .UP, .M = -INF, 0, +INF, 0)  1 so\_obj  ---- x selection of flow between i and j  x(1,2)  (.LO, .L, .UP, .M = 0, 0, +INF, 0)  -1 so\_obj  1 flow\_on\_node\_origin  -1 flow\_on\_node\_intermediate(2)  x(1,3)  (.LO, .L, .UP, .M = 0, 0, +INF, 0)  -1 so\_obj  1 flow\_on\_node\_origin  -1 flow\_on\_node\_intermediate(3)  x(2,4)  (.LO, .L, .UP, .M = 0, 0, +INF, 0)  -1 so\_obj  1 flow\_on\_node\_intermediate(2)  1 flow\_on\_node\_destination  REMAINING 2 ENTRIES SKIPPED  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:55:18 Page 4  Shortest Path Problem  Model Statistics SOLVE shortest\_path\_problem Using LP From line 43  MODEL STATISTICS  BLOCKS OF EQUATIONS 4 SINGLE EQUATIONS 5  BLOCKS OF VARIABLES 2 SINGLE VARIABLES 6  NON ZERO ELEMENTS 16  GENERATION TIME = 0.110 SECONDS 4 MB 32.2.0 rc62c018 WEX-WEI  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:55:18 Page 5  Shortest Path Problem  Solution Report SOLVE shortest\_path\_problem Using LP From line 43  S O L V E S U M M A R Y  MODEL shortest\_path\_problem OBJECTIVE z  TYPE LP DIRECTION MINIMIZE  SOLVER CPLEX FROM LINE 43  \*\*\*\* SOLVER STATUS 1 Normal Completion  \*\*\*\* MODEL STATUS 1 Optimal  \*\*\*\* OBJECTIVE VALUE 2.0000  RESOURCE USAGE, LIMIT 0.031 10000000000.000  ITERATION COUNT, LIMIT 0 2147483647  IBM ILOG CPLEX 32.2.0 rc62c018 Released Aug 26, 2020 WEI x86 64bit/MS Window  \*\*\* This solver runs with a demo license. No commercial use.  Cplex 12.10.0.0  Space for names approximately 0.00 Mb  Use option 'names no' to turn use of names off  LP status(1): optimal  Cplex Time: 0.02sec (det. 0.01 ticks)  Optimal solution found.  Objective : 2.000000  LOWER LEVEL UPPER MARGINAL  ---- EQU so\_obj . . . 1.000  ---- EQU flow\_on\_n~ 1.000 1.000 1.000 1.000  so\_obj define objective function  ---- EQU flow\_on\_node\_intermediate  LOWER LEVEL UPPER MARGINAL  2 . . . EPS  3 . . . .  LOWER LEVEL UPPER MARGINAL  ---- EQU flow\_on\_n~ 1.000 1.000 1.000 1.000  LOWER LEVEL UPPER MARGINAL  ---- VAR z -INF 2.000 +INF .  ---- VAR x selection of flow between i and j  LOWER LEVEL UPPER MARGINAL  1.2 . 1.000 +INF .  1.3 . . +INF .  2.4 . 1.000 +INF .  3.2 . . +INF 1.000  3.4 . . +INF EPS  \*\*\*\* REPORT SUMMARY : 0 NONOPT  0 INFEASIBLE  0 UNBOUNDED  GAMS 32.2.0 rc62c018 Released Aug 26, 2020 WEX-WEI x86 64bit/MS Windows - 10/13/20 07:55:18 Page 6  Shortest Path Problem  E x e c u t i o n  ---- 45 VARIABLE x.L selection of flow between i and j  2 4  1 1.000  2 1.000  ---- 46 VARIABLE z.L = 2.000  EXECUTION TIME = 0.313 SECONDS 4 MB 32.2.0 rc62c018 WEX-WEI  USER: GAMS Demo license for Dr. Zhou G200810|0002CO-GEN  Arizona State Univeristy, United States of America DL014724  \*\*\*\* FILE SUMMARY  Input C:\Users\Adam Tran\Documents\CEE598 \_TrafficSimulation\gams\_codes\2\_S  hortest path problem.gms  Output C:\Users\Adam Tran\Documents\gamsdir\projdir\2\_Shortest path problem.  lst |