

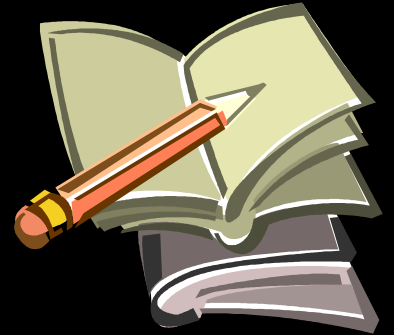
# **International Logistics**

## **Travelling Salesman Problem (TSP)**

### **Workshop 5a**



# ***Project***



***How to plan the shortest route to connect  
several different logistics points?***

# Travelling Salesman Problem



**TSP** – general characteristics:

- Irish mathematician W. R. Hamilton defined the TSP in XIX century.
- **TSP** was first formulated as problem in 1930 and is one of the most intensively studied problems in logistics / transportation optimization.
- How to find the shortest route when we take into consideration many cities – points of business / interest?

# Travelling Salesman Problem



**TSP** – computing a solution:

- How many solutions are there ?

Formula =  $(n \text{ points} - 1)!$  (factorial) / 2

- For 10 points we have 181 440 solutions
- For 15 points we have 43 589 145 600 solutions
- SOLUTION: heuristic algorithms (probability) / software application

# TSP — EUROPE (1):

*How to build the most cost effective transportation system for European capitals by implementing TSP?*

Europe



# TSP – EUROPE:

## Methodology:

1. Define the main objective and the scope of the project.
2. Choose the appropriate tool to solve the problem (Solver).
3. Create the list of all the point of your interest.
4. Define coordinates values for the points.
5. Create a Distance table between the points.
6. Perfome calculations – check point 2.
7. Deliver the answer.



# TSP for EUROPE?

| Rank | City                                                                                          | country        |
|------|-----------------------------------------------------------------------------------------------|----------------|
| 1.   |  Ankara       | Turkey         |
| 2.   |  Moscow       | Russia         |
| 3.   |  Baku         | Azerbaijan     |
| 4.   |  London       | United Kingdom |
| 5.   |  Podgorica    | Montenegro     |
| 6.   |  Rome         | Italy          |
| 7.   |  Berlin       | Germany        |
| 8.   |  Kiev         | Ukraine        |
| 9.   |  Tbilisi      | Georgia        |
| 10.  |  Zagreb       | Croatia        |
| 11.  |  Madrid       | Spain          |
| 12.  |  Skopje       | Macedonia      |
| 13.  |  Budapest   | Hungary        |
| 14.  |  Warsaw     | Poland         |
| 15.  |  Prague     | Czech Republic |
| 16.  |  Sofia      | Bulgaria       |
| 17.  |  Vienna     | Austria        |
| 18.  |  Vilnius    | Lithuania      |
| 19.  |  Bratislava | Slovakia       |
| 20.  |  Belgrade   | Serbia         |

|     |                                                                                                     |                        |
|-----|-----------------------------------------------------------------------------------------------------|------------------------|
| 21. |  Riga              | Latvia                 |
| 22. |  Minsk             | Belarus                |
| 23. |  Oslo              | Norway                 |
| 24. |  Ljubljana         | Slovenia               |
| 25. |  Reykjavík         | Iceland                |
| 26. |  Bucharest         | Romania                |
| 27. |  Yerevan           | Armenia                |
| 28. |  Amsterdam         | Netherlands            |
| 29. |  Stockholm         | Sweden                 |
| 30. |  Helsinki          | Finland                |
| 31. |  Tallinn           | Estonia                |
| 32. |  Sarajevo          | Bosnia and Herzegovina |
| 33. |  Chişinău          | Moldova                |
| 34. |  Dublin          | Republic of Ireland    |
| 35. |  Paris           | France                 |
| 38. |  Copenhagen      | Denmark                |
| 39. |  Lisbon          | Portugal               |
| 40. |  Bern            | Switzerland            |
| 41. |  Luxembourg City | Luxembourg             |
| 42. |  Tirana          | Albania                |
| 43. |  Athens          | Greece                 |

|     |                                                                                                        |               |
|-----|--------------------------------------------------------------------------------------------------------|---------------|
| 44. |  City of Brussels   | Belgium       |
| 45. |  Andorra la Vella   | Andorra       |
| 46. |  Vaduz              | Liechtenstein |
| 47. |  City of San Marino | San Marino    |
| 48. |  Monaco             | Monaco        |
| 49. |  Valletta           | Malta         |
| 50. |  Vatican City       | Vatican City  |



# TSP – EUROPE (2):

|  | CITY             | point |
|--|------------------|-------|
|  | Warsaw           | 0     |
|  | Kiev             | 1     |
|  | Budapest         | 2     |
|  | Prague           | 3     |
|  | Amsterdam        | 4     |
|  | Stockholm        | 5     |
|  | Moscow           | 6     |
|  | Madrid           | 7     |
|  | Sofia            | 8     |
|  | Vienna           | 9     |
|  | Vilnius          | 10    |
|  | Bratislava       | 11    |
|  | Belgrade         | 12    |
|  | Riga             | 13    |
|  | Oslo             | 14    |
|  | Athens           | 15    |
|  | Copenhagen       | 16    |
|  | Bern             | 17    |
|  | Lisbon           | 18    |
|  | Andorra la Vella | 19    |

TSP for EUROPE?



| cj | 0     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    | 18    | 19    |
|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0  | 0     | 770   | 700   | 630   | 1 260 | 1 630 | 1 300 | 3 070 | 1 480 | 740   | 480   | 730   | 1 090 | 700   | 1 630 | 2 325 | 1 010 | 1 430 | 3 830 | 2 350 |
| 1  | 770   | 0     | 1 160 | 1 600 | 2 035 | 3 570 | 870   | 3 750 | 1 310 | 1 420 | 740   | 1 270 | 1 510 | 1 210 | 4 150 | 2 210 | 1 790 | 2 290 | 4 510 | 3 090 |
| 2  | 700   | 1 160 | 0     | 570   | 1 530 | 1 960 | 2 030 | 2 710 | 780   | 270   | 1 190 | 210   | 390   | 1 630 | 1 950 | 1 620 | 1 340 | 1 130 | 3 470 | 2 050 |
| 3  | 630   | 1 600 | 570   | 0     | 830   | 1 400 | 1 930 | 2 390 | 1 450 | 300   | 1 100 | 330   | 1 070 | 1 330 | 1 390 | 2 300 | 780   | 800   | 3 060 | 1 590 |
| 4  | 1 260 | 2 035 | 1 530 | 830   | 0     | 1 350 | 2 570 | 1 750 | 2 205 | 1 260 | 1 660 | 1 330 | 1 820 | 1 960 | 1 345 | 3 050 | 730   | 845   | 2 545 | 1 530 |
| 5  | 1 630 | 3 570 | 1 960 | 1 400 | 1 350 | 0     | 3 050 | 3 240 | 3 100 | 1 690 | 3 250 | 1 740 | 2 720 | 2 950 | 580   | 3 950 | 620   | 1 050 | 4 000 | 2 600 |
| 6  | 1 300 | 870   | 2 030 | 1 930 | 2 570 | 3 050 | 0     | 4 380 | 2 770 | 2 010 | 920   | 2 360 | 2 380 | 950   | 2 930 | 3 080 | 2 320 | 2 730 | 5 140 | 3 710 |
| 7  | 3 070 | 3 750 | 2 710 | 2 390 | 1 750 | 3 240 | 4 380 | 0     | 3 130 | 2 430 | 3 550 | 2 490 | 2 740 | 3 770 | 3 230 | 3 970 | 2 620 | 1 590 | 760   | 630   |
| 8  | 1 480 | 1 310 | 780   | 1 450 | 2 205 | 3 100 | 2 770 | 3 130 | 0     | 1 150 | 1 970 | 940   | 385   | 2 190 | 3 100 | 900   | 2 480 | 1 800 | 3 890 | 2 470 |
| 9  | 740   | 1 420 | 270   | 300   | 1 260 | 1 690 | 2 010 | 2 430 | 1 150 | 0     | 1 220 | 70    | 770   | 1 440 | 1 690 | 2 000 | 1 070 | 870   | 3 290 | 1 770 |
| 10 | 480   | 740   | 1 190 | 1 100 | 1 660 | 3 250 | 920   | 3 550 | 1 970 | 1 220 | 0     | 1 210 | 1 580 | 300   | 1 830 | 2 810 | 1 490 | 1 910 | 4 310 | 2 830 |
| 11 | 730   | 1 270 | 210   | 330   | 1 330 | 1 740 | 2 360 | 2 490 | 940   | 70    | 1 210 | 0     | 540   | 1 430 | 1 910 | 1 740 | 1 260 | 940   | 3 350 | 1 830 |
| 12 | 1 090 | 1 510 | 390   | 1 070 | 1 820 | 2 720 | 2 380 | 2 740 | 385   | 770   | 1 580 | 540   | 0     | 1 790 | 2 710 | 1 230 | 2 100 | 1 410 | 3 500 | 1 830 |
| 13 | 700   | 1 210 | 1 630 | 1 330 | 1 960 | 2 950 | 950   | 3 770 | 2 190 | 1 440 | 300   | 1 430 | 1 790 | 0     | 2 950 | 3 020 | 1 430 | 2 120 | 4 530 | 3 050 |
| 14 | 1 630 | 4 150 | 1 950 | 1 390 | 1 345 | 580   | 2 930 | 3 230 | 3 100 | 1 690 | 1 830 | 1 910 | 2 710 | 2 950 | 0     | 3 940 | 610   | 1 820 | 3 990 | 2 720 |
| 15 | 2 325 | 2 210 | 1 620 | 2 300 | 3 050 | 3 950 | 3 080 | 3 970 | 900   | 2 000 | 2 810 | 1 740 | 1 230 | 3 020 | 3 940 | 0     | 3 330 | 2 720 | 4 730 | 3 320 |
| 16 | 1 010 | 1 790 | 1 340 | 780   | 730   | 620   | 2 320 | 2 620 | 2 480 | 1 070 | 1 490 | 1 260 | 2 100 | 1 430 | 610   | 3 330 | 0     | 1 210 | 3 370 | 2 100 |
| 17 | 1 430 | 2 290 | 1 130 | 800   | 845   | 1 050 | 2 730 | 1 590 | 1 800 | 870   | 1 910 | 940   | 1 410 | 2 120 | 1 820 | 2 720 | 1 210 | 0     | 2 350 | 960   |
| 18 | 3 830 | 4 510 | 3 470 | 3 060 | 2 545 | 4 000 | 5 140 | 760   | 3 890 | 3 290 | 4 310 | 3 350 | 3 500 | 4 530 | 3 990 | 4 730 | 3 370 | 2 350 | 0     | 1 390 |
| 19 | 2 350 | 3 090 | 2 050 | 1 590 | 1 530 | 2 600 | 3 710 | 630   | 2 470 | 1 770 | 2 830 | 1 830 | 1 830 | 3 050 | 2 720 | 3 320 | 2 100 | 960   | 1 390 | 0     |