Flight Maps

GIS and Spatial Analysis

Report

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Introduction

Several flights throughout the world each day. These flights do not go linearly in straight line in geographical plane. There are many deviations from straight path exists due to several constraints. The constraint was not to flyover a selected country. The constraint in real time could be because of several reasons such as atmospheric conditions such as extreme rain or cross wind patterns, airline policies, airline preferences, air control regulations, strikes, and geopolitical situations. In any of such case, these constraint comes into effect for flight path. The plane have to altered longer path to complete its flight. In this assignment, the situation given was to calculate Direct Flight path and flight path under a given constraint was calculated between two cities using ArcGIS. In this casel the selected country was Deutschland (Germany). The two cities have to be selected from the list of given cities. So, the flight paths were calculated for flight from London to Warsaw. Deutschland lies in between London and Warsaw. Therefore, if the constraint is not to fly over Germany, then the flight path would be altered significantly which can be observed in the results of this assignment as well. This irregular flight path pattern could be delineated and tackled in a considerate way by help of following exercise. Also, the resultant path in this exercise shows the optimal (best possible) path in terms of distance traveled during the flight.

Data

The total number of files in data were 13. The data consist of vector (11) and raster files(13). vector files were in shapefile format (.shp) while the raster files were in tif format (.tif). Vector files contained points of 10 cities in shapefile format. The 10 cities are in ten different countries of Europe. Point location of following cities were given in the shapefile:

Table 1: List of Cities with precise location

Athens (Greece)
Bonn (Germany)
London (England)
Paris (France)
Prague (Czech Republic)
Madrid (Spain)
Kiev (Ukraine)
Rome (Italy)
Stockholm (Sweden)
Warsaw (Poland)

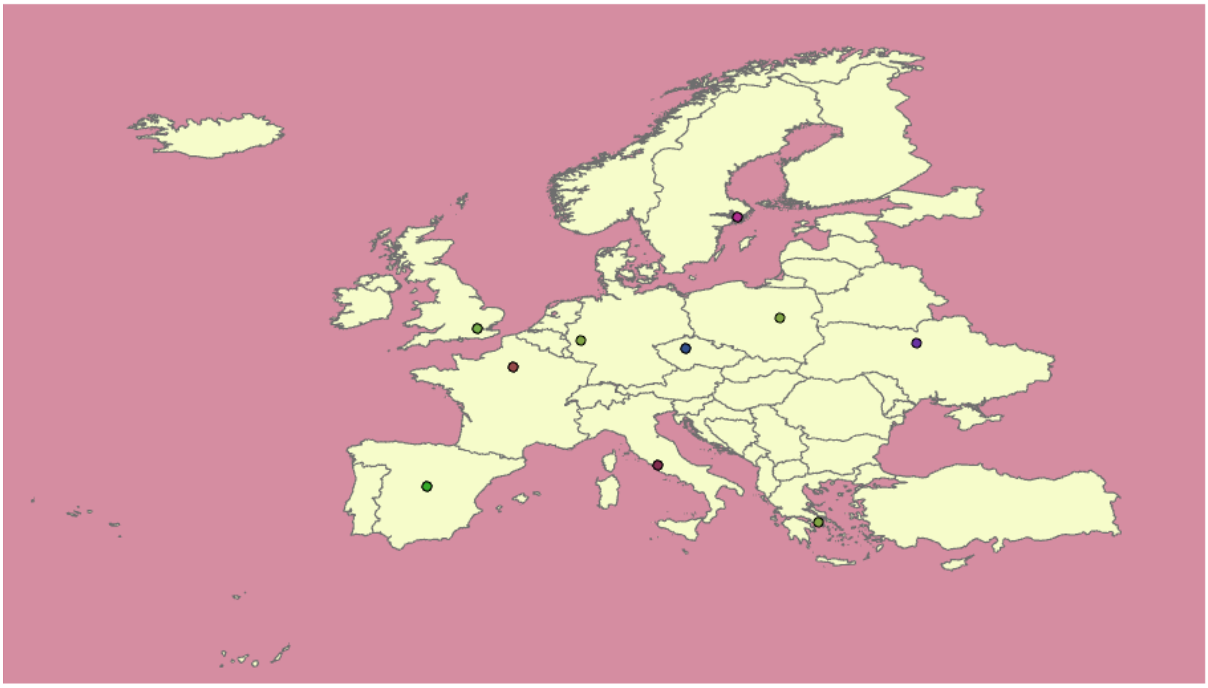

Figure 1: Geographical Location of Countries with their borders (red dots shows the main cities)

The countries shapefile contained 45 countries.

Table 2: Countries with IDs

ID	NAME
1	ANDORRA
2	ALBANIA
3	AUSTRIA
4	BELGIUM
5	BULGARIA
6	BOSNIA-HERCEGOVINA
7	BELARUS
8	SWITZERLAND
9	CYPRUS
10	CZECH REPUBLIC
11	GERMANY
12	DENMARK
13	SPAIN
14	ESTONIA
15	FINLAND
16	LIECHTENSTEIN
17	FRANCE
18	GREECE
19	HUNGARY
20	CROATIA
21	IRELAND
22	ICELAND
23	ITALY
24	LITHUANIA
25	LUXEMBOURG (GRAND-DUCHE)

26	LATVIA
27	MALTA
28	MONACO
29	MACEDONIA
30	MOLDOVIA
31	MONTENEGRO
32	NORWAY
33	NETHERLANDS
34	POLAND
35	PORTUGAL
36	ROMANIA
37	RUSSIA
38	SERBIA
39	SWEDEN
40	SLOVAKIA
41	SLOVENIJA
42	SAN MARINO
43	TURKEY
44	UKRAINE
45	UNITED KINGDOM

The spatial coordinate reference system used for the raster files was WGS 84 (World Geodetic System). It is one of the most widely used spatial reference system. The attributes of WGS84 are listed below:

Table 3: Attributes of Spatial Reference System WGS84

Unit: degree (supplier to define representation)
Geodetic CRS: WGS 84
Datum: World Geodetic System 1984 ensemble
Data source: EPSG
Information source: EPSG. See 3D CRS for original information source.
Revision date: 2020-03-14
Scope: Horizontal component of 3D system.
Area of use: World.
Coordinate system: Ellipsoidal 2D CS. Axes: latitude, longitude. Orientations: north, east. UoM: degree
Center coordinates 0.0 0.0
WGS84 bounds: -180.0 -90.0 180.0 90.0

Methodology

The methodology includes

- Reclassification
- Cost and Back Link Raster Calculation
- Cost path polyline delineation

It is to be noted that activated Spatial Analyst extension are required to run these tools in ArcGIS.

For this exercise, I choose " Deutchschland " (Germany) as the country with no fly zone and its ID number is 11. This ID number can be found in the attribute table of countries shapefile.

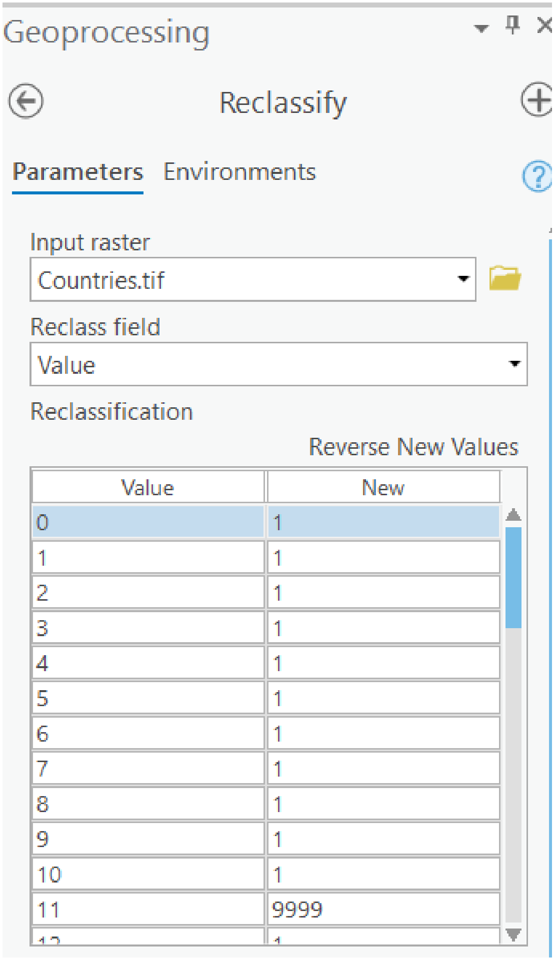

Figure 2: Reclassification Tool

Reclassify is a commonly used tool of ArcGIS. To use reclassify tool, it needs to be emphasized that spatial extension for spatial analyst toolbar needs to enabled. With the Spatial Analyst toolbar, you can perform a wide range of cell-based GIS operations. You can use the interactive tools on the toolbar to create a histogram and individual contours. Spatial operations that can be performed include distance, density, interpolation, reclassification, local (per-cell), neighborhood (focal), zonal, and surface, as well as conversion between feature and raster (Mittapalli et al., 2012). You can also work with the Raster Calculator to perform mathematical calculations using operators and functions, set up selection queries, or type in Map Algebra syntax to build expressions that will execute as a single command.

By reclassifying, one can modify the values in an input raster and save the changes to a new output raster.
There are many reasons why you may want to do this, including replacing values based on new information, grouping entries, reclassifying values to a common scale (for example, for use in suitability analysis), setting specific values to NoData, or setting NoData cells to a value (Jiménez-Perálvarez et al., 2009).

Reclassified the countries raster with new unique values. The reclassification tool takes a given input raster and updates its attribute values as required. All of the countries new value was set to 1 while for Deutschland it was set to 9999.

Due to large value of the selected country, it is highlighted in the output raster. The reclassified raster can be visualized as follows while the selected country is highlighted in green:

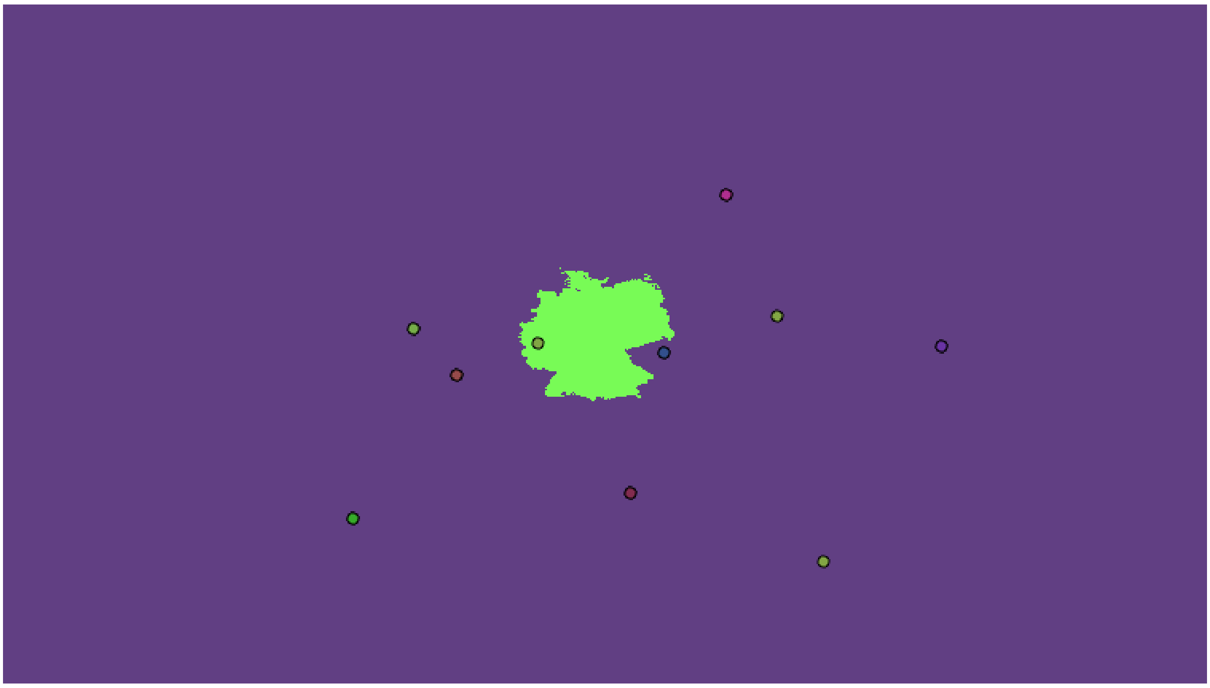

Figure 3: Reclassified Raster (points shows the location of main cities)

Selection of flight: For this exercise, I choose to fly from London (England) to Warsaw (Poland). The selection was made considering the fact that Deutschland (Germany) falls in between the two cities. This would make results clear and interesting.

The following steps were repeated for normal cost and for reclassified cost data.

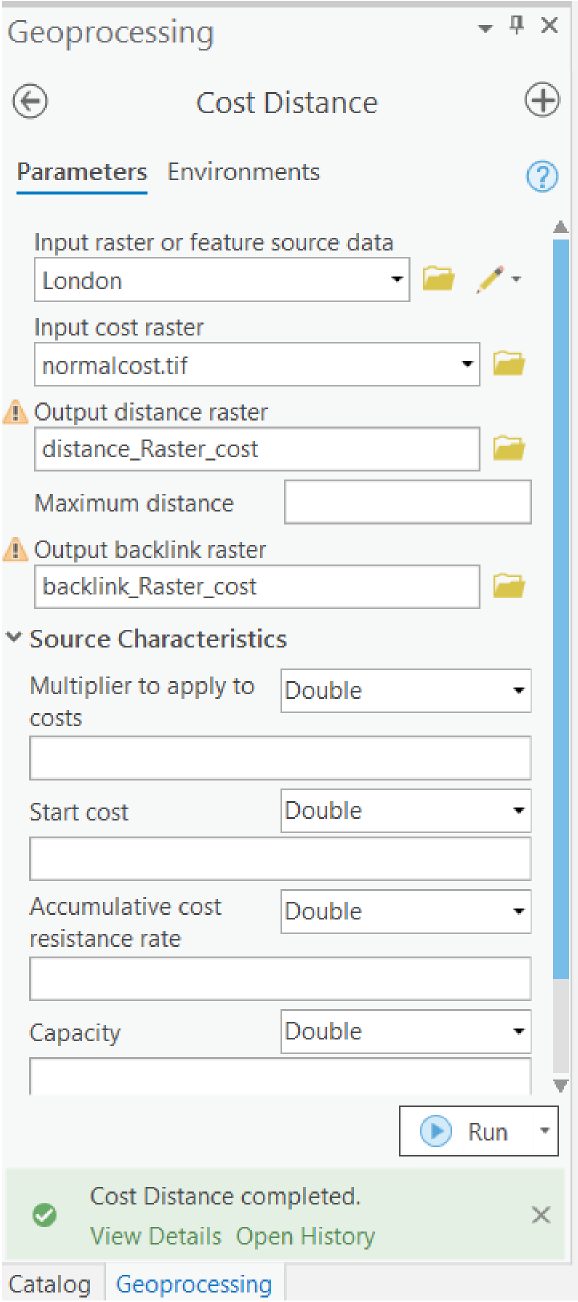

Figure 4: Cost Distance Tool in ArcGIS

The cost distance tool takes input point feature, the source (London) and input cost raster to generate an output distance raster and backlink raster. The normal cost raster was provided in the data already. Source Characteristics were left as blank while all other optional parameters of the tool were left with default value in order to run the tool.

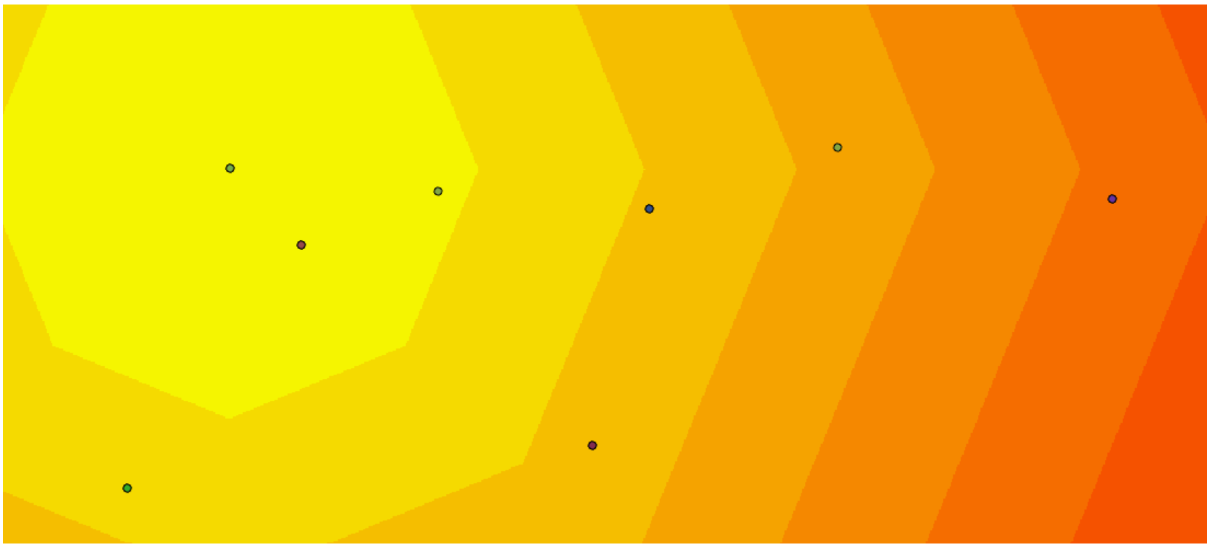

Figure 5: Normal Cost Raster

The increasing distance from the source results in increased cost that is indicated by gradual increase in intensity of the color. Same intensity of color shows region of similar cost value though there is slight difference of cost value within those regions.

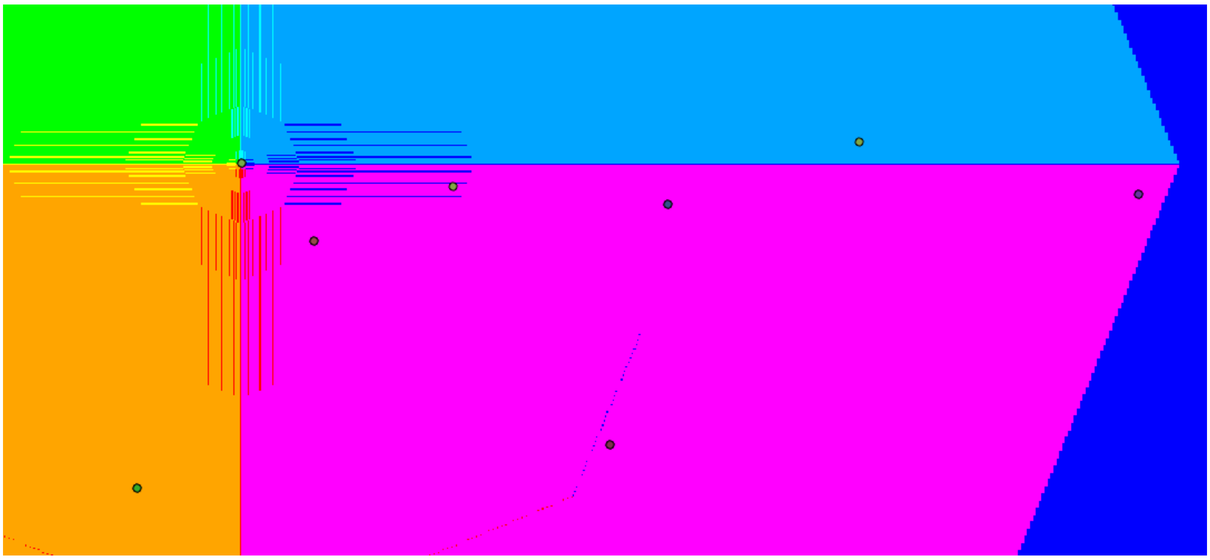

Figure 6: Back Link Raster

The Back Link Raster shows the direction from the source. In the above Figure 6, different colors represent different directions from the source point. Our destination (Warsaw) falls towards the right of the source location (London).

While the output cost-distance raster identifies the accumulative cost for each cell to return to the closest source location, it does not show which source cell to return to or how to get there. The Cost Back Link tool returns a direction raster as output, providing what is essentially a road map that identifies the route to take from any cell, along the least-cost path, back to the nearest source. By default, this tool will use 50 percent of the available cores. If the input data is smaller than 5,000 by 5,000 cells in size, fewer cores may be used. You can control the number of cores the tool uses with the Parallel processing factor environment. The cost distance tools are similar to Euclidean tools, but instead of calculating the actual distance from one location to another, the cost distance tools determine the shortest weighted distance (or accumulated travel cost) from each cell to the nearest source location. These tools apply distance in cost units, not in geographic unit.

For reclassified cost raster repeated the above step to calculate modified cost raster and backlink raster. In the two output raster files, the obstructed geographical region can be seen prominently. The visualizations of Cost Raster and Back link Raster for reclassified input are shown below:

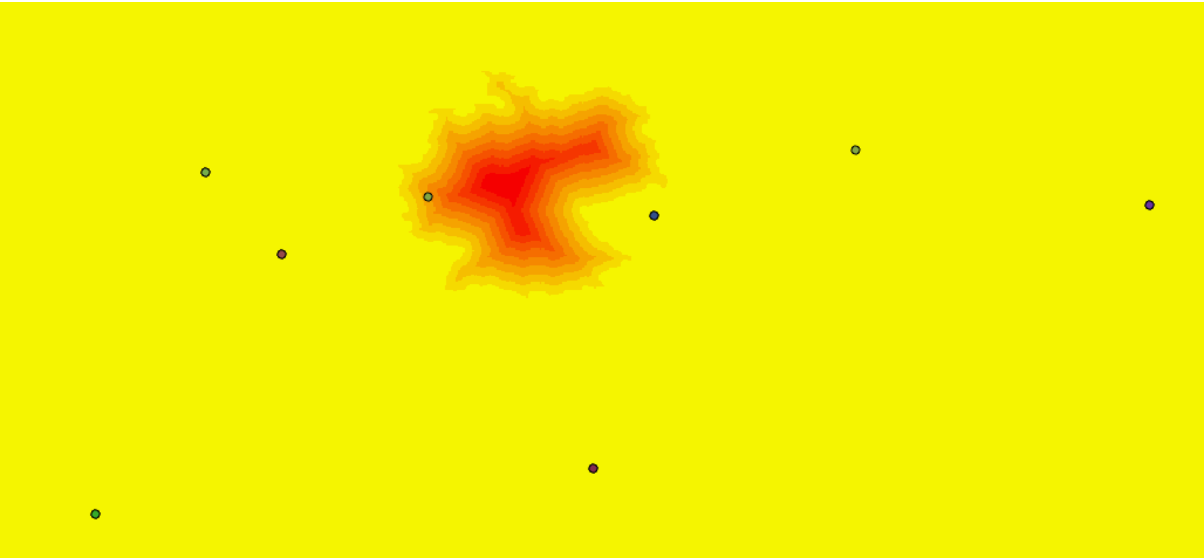

Figure 7: Modified Cost Raster for reclassified input data

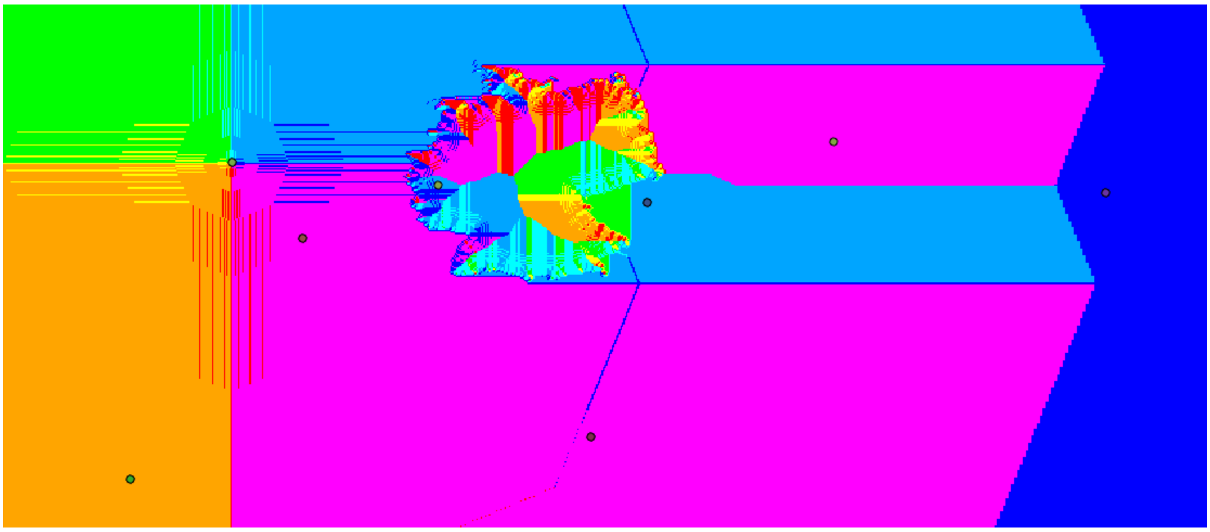

Figure 8: Back Link Raster for reclassified input data

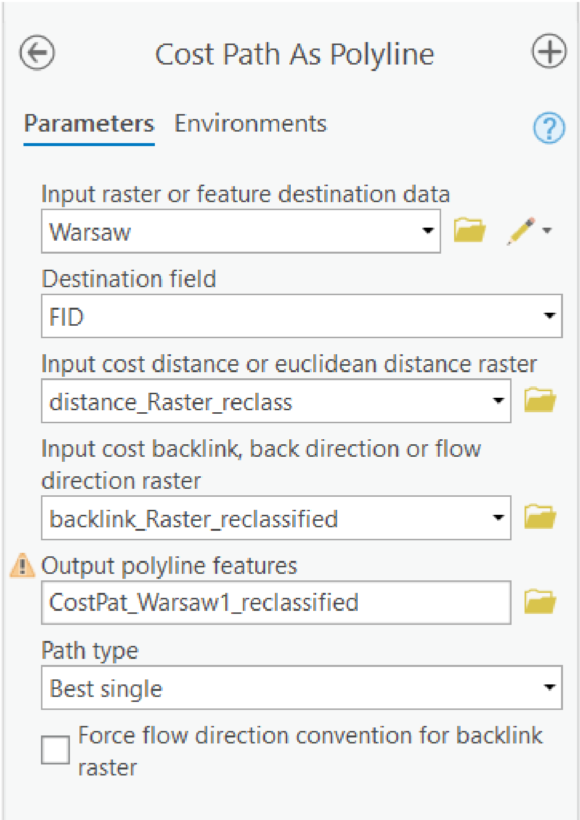

Figure 9: Cost path as polyline Tool

Using Cost Path as Polyline tool, calculated the cost path polyline between London and Warsaw. The cost path as polyline tool takes as input the output of cost distance tool that is cost distance raster and backlink raster in addition it also takes the destination point as input. As for generating the cost raster, source point was given and the calculations were made based on that point, so therefore with addition of destination of point, both of required points are there for the tool to delineate the path as a polyline feature. All other parameters were left with the default value.

This tool generally calculates the least-cost path from a source to a destination as a line feature. Cost Path as Polyline can be used to determine the flow path based on D8 flow direction. To use Cost Path as Polyline in this way, use a D8 flow direction raster as input for the Input cost backlink raster. You also need to supply an Input cost distance raster; the Input cost distance raster is not used to determine the path. Whether you use a constant raster or a digital elevation model (DEM), your path will be the same; only an attribute value on your path will vary. The researcher (Kang and Lee, 2017) very efficiently used the tool for optimization of path.

Results

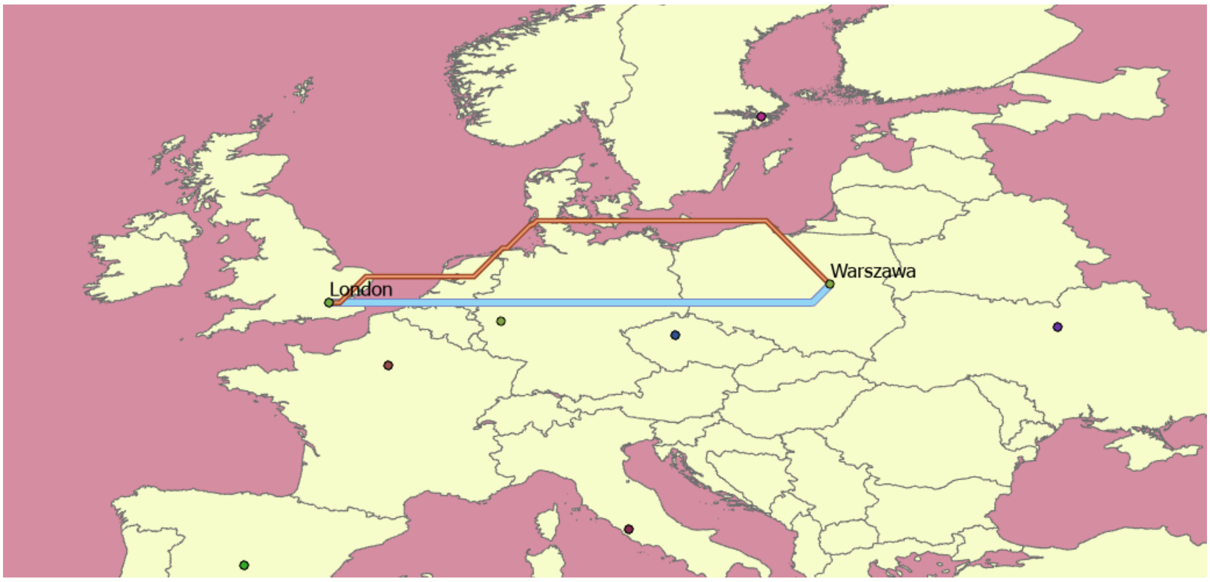

Figure 10: Visualization of Resultant Polylines from London to Warsaw

In the above figure, the two lines corresponds to two flight paths. Blue line shows the direct flight path from London to Warsaw while the red line shows the flight path avoiding the no fly country (Germany).

It is evident just from the visualization that the blue line is much shorter than the red line.

The measure tool curves the measuring line due to curvature of Earth in order to avoid such situation, smaller segments were taken and then they were added up to measure the total distance between the two cities. In this way, the measuring line overlayed more accurately on the flight path and hence, the measured distance was more accurate.

The calculated distance for shortest flight is 98.61 kilometers. While the distance for the flight path avoiding the no fly country is 352.62 kilometers.

Similarly, calculated and found the cost path from other cities to Warsaw within and without constraint. Following table shows the results of the procedure.

Table 4: Resultant Distances from source cities to destination Warsaw keeping Germany as no fly zone

From	To	Normal	With Constraint
London	Warsaw	98.61 km	352.62 km
Paris	Warsaw	446.23 km	660.05 km
Madrid	Warsaw	730.86 km	730.86 km
Prague	Warsaw	122.07 km	122.07 km
Stockholm	Warsaw	236.76 km	236.76 km
Athens	Warsaw	355.35 km	355.35 km
Kiev	Warsaw	238.71 km	238.71 km
Rome	Warsaw	432.06 km	432.06 km

In the following, map shows the polylines from source to destination cities.

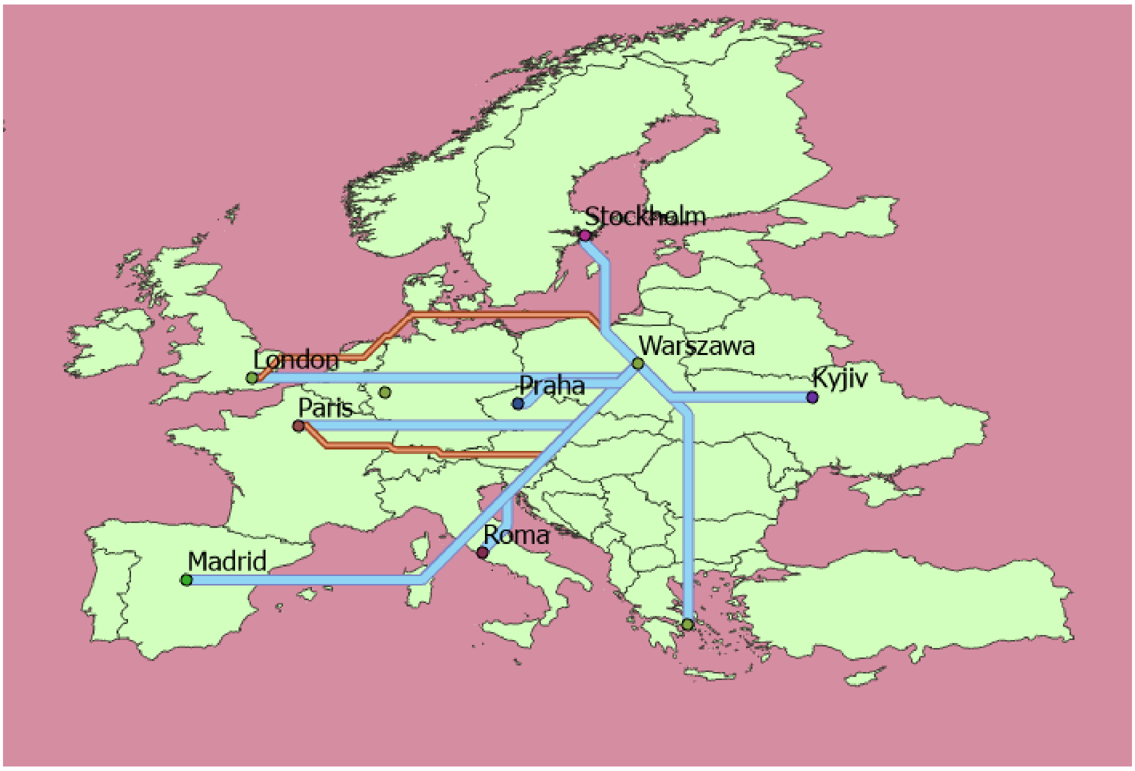

Figure 11: Map with polylines from source cities to destination Warsaw keeping Germany as no fly zone

It can be observed that only two cities London and Paris that have different pathways under a the constraint. It is because these are the only two cities that geographically lies directly between the source and destination, therefore, these cities show altered paths. While all other cities show one path for both distances calculations. It maybe noted that name of some cities might not be same in the above figure. These are the commonly used localized name for these cities.

Now, changed the no fly zone to Poland to calculate the normal distance and distance under constraint. Poland had the ID number 34. Reclassified its value to extremely high value. Also, Changed the Destination to Kiev (Ukraine). Repeated all of the above procedure for the changes for calculating the distances.

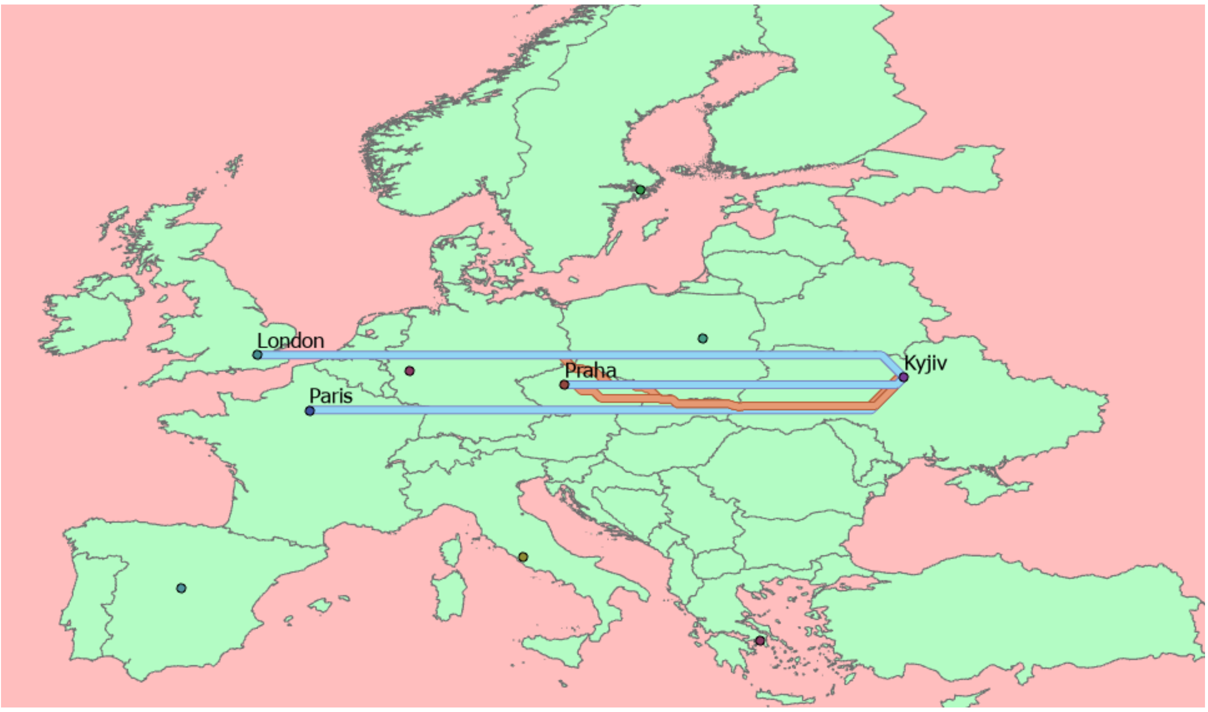

Figure 12: Map with Polyline keeping Kiev as destination while Poland as no fly-zone.

Table 5: Resultant Distances from source cities to destination Kiev keeping Poland as no fly zone

From	To	Normal	With Constraint
London	Kiev	2204.91 km	2630.22 km
Paris	Kiev	2030.07 km	2030.07 km
Prague	Kiev	1178.58 km	1315.66 km

Conclusion

Through the exercise it can be observed that ArcGIS can be used to tackle real life problems and scenarios. It can be used to find the distances accurately. However, the accuracy of these measurements is greatly dependent and also limited by the accuracy of Coordinate Reference System (CRS). The accuracy and precision of the calculated distances cannot be more than the accuracy of CRS. Also, selection of proper CRS is vital otherwise, the calculations would be highly inaccurate. For this assignment, the spatial reference system was WGS84 (World Geodetic System: 4326). It is generally good in certain aspects but also has some limitations as every reference system has few positive and negative aspects. In some cases, the calculated distance for modified flight path was 353 km while for direct flight was 99 km which almost 3.5 times more than the direct flight distance. Hence, no fly zone can greatly increase the distance covered to fly from point A to point B.

References

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