Network Analysis of Salzburg

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Connectivity is productivity.
It's true for a modern office, and also for any place, [even] for an undeveloped village.
-Iqbal Quadir

Abstract

The Network Analysis Tools of ArcGIS Online and ArcGIS Pro are incredibly versatile tools that make some complicated mathematical problems easily solvable with just a few clicks.

On this report, I explore several of them in the context of Tourist Attractions in the Austrian City of Salzburg.

Keywords: ArcGIS Online, ArcGIS Pro, Network Analysis

Introduction

My setup to proceed with the network analysis of Salzburg consisted of the following datasets:

- Open Street Map (OSM) Tourist Attractions for Europe
- Kindergarten and Schools of the Province of Salzburg
- My home address, which is right on campus, in Techno-Z
- The ESRI "Community Maps" background map

After this, I was ready to start analyzing!

All my (fully interactable) maps were uploaded to the class group on ARCGis Online as Pro Map Files. Here, I've included screenshots of the ones I thought were paramount for a better understanding of the text.

1 First Task

For the Task 1, I was asked to explore how many tourist attractions were within a 5, 10, 15, and 20 minute-walking distance from my home. To do so, I generated a "travel area", as it is called in ArcGIS Online (the equivalent to the "service area", on ArcGIS Pro) using ArcGIS's own datasets. However, I quickly noticed something wasn't right. To better understand what was happening, I asked the program to find the best route to several points in my vicinity, and the outcome made my problem obvious: ArcGIS's datasets were missing some pedestrian paths, including the ones that traverse the campus and connect it to the main roads.

Determined to get the most accurate result possible, I downloaded my project to work on it with ArcGIS Pro, which allows me to use my own network data. There was one thing left to do: find myself a reliable network. I searched for several datasets, both on ArcGis Online and other platforms, but they all had something wrong, and, after five hours of trying, I was nowhere closer to getting a more accurate network. Finally, I decided to query OSM to get all the roads and paths from Salzburg (and an additional 5km buffer area), and "Voilá"! It worked!

I excluded highways and other car-exclusive roads, and created a spatial database with that data, followed by a network, and then proceeded to generate the "travel area" rings around my home. Since I no longer had the option to generate the rings based on traveling time, I had to assume a walking speed of 5km/h ($\approx$ 83,33 m/s) and then generate the rings based on traveling distance instead. Finally, I used the "Intersect" tool to find which

attractions were included in my rings. In the Annex, on section 5, I've included a map of the resulting travel area shapes (in Figure 4), as well as a map of the travel area shapes generated using ArcGIS's own datasets (Figure 5). The values of the measured areas accessible by foot in 5, 10, 15, and 20 minutes for the two methods can be seen in Table 1.

	ArcGIS-calculated Area (km^2)	OSM-calculated Area (km^2)
5 min.	0,37	0,35
10 min.	1,3	1,3
15 min.	2,6	2,9
20 min.	4,4	4,9

Table 1: Cumulative Areas for the different walking traveling times, using the two different datasets.

It's curious that the innermost ring is smaller for the OSM-calculated area, even though more area is accessible for the other thresholds.

In total, the OSM-calculated areas include 41 touristic destinations, of which 11 are reachable in less than 5 minutes, with an additional 4 being reachable in less than 10 minutes, and an additional 10 in less than 15 minutes. Among these, there are 15 information booths, 10 hotels, 6 artworks, 4 guest houses, 3 picnic sites (all in Techno-Z), 2 museums, and 1 hostel.

2 Second Task

For Task 2, I was asked to find the 5 closest museums with respect to Driving and Walking around my home. For the walking part, the network I created for Task 1 was more than suitable. For the driving part, it would be more complicated: not only would I have to create a new network that doesn't take into account the footpaths, I would also have to somehow make the model aware of speed limits. Furthermore, considering that ArcGIS's own datasets were only missing pedestrian paths (at least, to my knowledge), I figured they were the best solution for the driving part.

I then generated a "closest facility" layer with each of the networks, I filtered the OSM Tourist Attractions layer to museums, and added them as "facilities" before running the algorithm. The results were quite interesting.

2.1 Walking

The 5 closest museums to my home, when traveling by foot, are all south of my home, and they are (from closest to furthest): the iDEAS Lab (at a distance of 79m), Bible World (1028m away), the Stadt-Galerie (2209m away), the Mozart Residence (2570m away), and Moon City (2676m away).

2.2 Driving

The 5 closest museums to my home, when traveling by car, are more dispersed than the ones on section 2.1. They are (from fastest to quickest to get to): the iDEAS Lab (which, as seen on Figure 1, involves an unrealistic route, and is thus at a distance of 0,63km, which would take 2min30s. to travel), Bible World (at a distance of 0,94km, which would take approximately 3min. to travel), the world of Poisons (at a staggering distance of 3,7km, which would take only 7min. to travel), the Mozart Residence (at a distance of 2,7km, which would take approximately 8min. to travel), and finally Moon City (at a distance of 2,8km, which would take a bit more than 8min. to travel).

Figure 1: Detail of the resulting route to connect my home to the iDEAS Lab by car. The blue square, which represents my home, is closer to and thus projected on Jakob Haringer Street (which is even more surprising when compared with Figure 5, where the opposite happened, perhaps because I placed the pin in a slightly different location); while the blue circle, which represents the lab, is closer to the campus' parking lot, culminating in this absurd result.

3 Third Task

For Task 3, I was asked to find the 20 closest hotels around Getreidegasse with respect to walking, and I have never been happier for wasting time being thorough before! The whole process was extremely simple, or so I

thought (at first): I selected the elements with the name "Getreidegasse" on my OSM layer of roads and paths, ran the "Feature Vertices to Points" tool to get a point at each intersection with other streets and then used those points as "incidents" in the "closest facility" layer I had created for Task 2. Finally, I just had to filter my OSM Tourist Attractions layer again (this time for hotels), and add the resulting points as "facilities" before running the algorithm.

	Hotel	Distance (m)
1	Hotel Goldener Hirsch	31
2	Hotel Elephant	77
3	Art House	139
4	Stein	197
5	Radisson Blu Altstadt Hotel	197
6	Hotel am Dom	213
7	Gablerbräu	297
8	Hotel Sacher	300
9	arte vida	311
10	Stadtkrug	331
11	Hotel Schwarzes Rössl	332
12	Star Inn Hotel Gablerbräu	345
13	City-Hotel Trumer-Stube	395
14	Star Inn Hotel	402
15	Bristol	405
16	Hotel Goldene Krone	462
17	Pension zum jungen Fuchs	508
18	Hotel am Mirabellplatz	529
19	Hotel Amadeus	529
20	Kasererbraeu	582

Table 2: Length of the shortest path between Getreidegasse and the 20 closest hotels, ordered from shortest to longest. It should be noted that the distance to Hotel Goldener Hirsch doesn't have any real meaning, since that hotel is set on Getreidegasse.

Here's when things got tricky: the algorithm calculated the 20 closest hotels to each point, resulting in 1400 different paths!

At first I tried to fix this "manually". However, when I was halfway through, I realized it was taking a long time and I was promoting a rather non-scientific behavior. After feeling ashamed of myself, I did some research and ended up using the "Summary Statistics" tool. With it, I could "simulate" SQL queries and thus could find the smallest path to each hotel. But my job wasn't finished yet! For some reason that eludes me, the distance was being calculated in yards. Being an avid defender of the metric system, I couldn't stand for this, so I converted all the distances, and the final result can be seen on Table 2.

4 Fourth Task

Task 4 was two-fold. First, I was asked to find museums that are within a 10 minute-walking distance around Kindergarten (KG) locations in Salzburg. Then, I was asked to select one KG and calculate the best routes to connect all the selected museums using 1, 2, and 3 vehicles respectively, with no further capacity or time constraints

4.1 Museums in a walking-distance of Kindergartens

For this part, I used my OSM network, my filtered OSM Tourist Attractions Layer defined back in Task 2 and the Layer of the Kindergarten and Schools of the Province of Salzburg. I should note that this second layer was incomplete (probably because it is over a decade old), as it doesn't have the Techno-Z KG, for example. I actually downloaded the most recent version from the Government website and confirmed that te Techno-Z KG is now listed (amongst others). That being said, considering my OSM network doesn't extend to the whole state and considering the high density of KG in the city of Salzburg, I'm convinced the selected museums would be the same and thus ran the algorithms with the outdated layer.

In this part, the procedure was similar to the one described in Section 1 to generate the "service area". This time, it resulted in 18 museums being found within a 10 minute-walking distance of a KG. Of these:

- 15 are located in the city of Salzburg (even though one of them is very separate from the rest, close to the border with the municipality of Bergheim)
- 2, which have the same name ("Untersbergmuseum"), are in the municipality of Grödig, to the south of the city
- 1 is in the municipality of Ebenau, to the east of the city

4.2 Best Routes

For the second part, I used ArcGIS own datasets to create a "Vehicle Routing Problem" layer. I then selected the Techno-Z KG as my "depot", imported the museums as "orders" and created the routes starting from the Techno-Z KG. When I ran the problem, however, I encountered an error, which was due to the aforementioned two "Untersbergmuseum". I re-imported the museums as "orders", this time with the "ObjectID" field replacing the "name" field, and finally got things to work!

For the case with 1 bus, whose result can be seen on Figure 2, the ideal path consisted of heading north first,

to the border with Bergheim, and then head to city center, before going to Grödig. After that, return to the city center and proceed to Ebenau. The bus would travel a total distance of 56km, and the total elapsed time would be 123 minutes, i.e. a little over 2 hours. I expect this result to be the same I would have gotten with the "Make Route Analysis" tool.

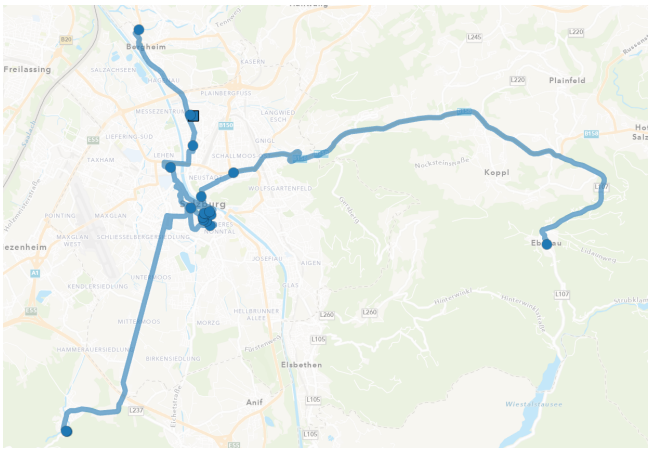

Figure 2: Best route calculated to visit all the museums in Salzburg (and vicinity) with 1 bus, departing from the Techno-Z KG. The dots represent the museums, while the square represents the KG.

The case with 2 buses is not very different, except one of the buses headed straight to Grödig and immediately returned to the "depot", while the other bus handled all the remaining 16 museums in a similar order as before. The first bus would thus travel 12km and be finished in 24 minutes, while the second one would travel 38km, taking 91 minutes to finish. This happens because the tool is minimizing total (combined) travel time, i.e. the sum of both times, which did indeed decrease in comparison to the 1-bus-case. In some instances, it would be much more important to minimize the maximum travel time, which would ensure the last bus finished as early as possible, even if the total travel time was higher.

For the case with 3 buses, whose result can be seen on Figure 3, one of the buses was once again assigned exclusively to Grödig, one bus was assigned exclusively to Ebenau, while the third bus handled all the remaining 15 museums. This time, the route of the last bus has some differences, since the Ebenau bus splits from the rest very early on. The first bus would thus travel the same 12km and be finished in 24 minutes, while the second one would travel 19km, taking 25 minutes to finish, and the third would travel 21km, taking 67 minutes to finish. What's interesting here is that the total travel time is actually (ever so slightly) larger than in the case with 2 buses, even if the last bus finishes more than 20 minutes earlier. In spite of the documentation not mentioning any of this, it led me to wonder if the algorithm was forced to assign at least one order to each of the buses.

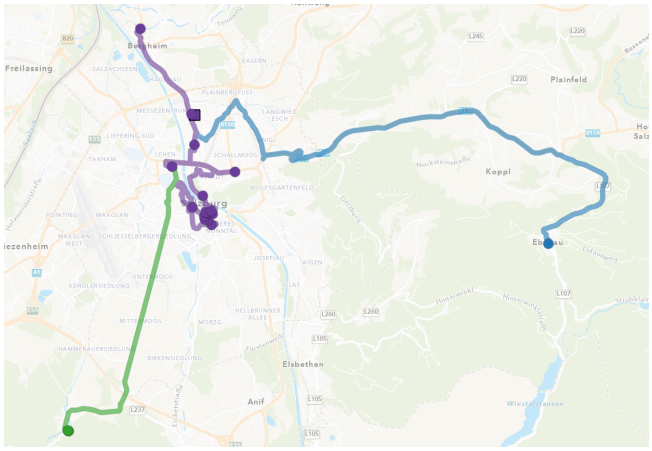

Figure 3: Best routes calculated to visit all the museums in Salzburg (and vicinity) with 3 buses, departing from the Techno-Z KG. The dots represent the museums, while the square represents the KG. The purple color is used to represent the path of the City Bus and the assigned museums, green is used for the Grödig Bus, and blue is used for the Ebenau Bus.

To assess my hypothesis, I calculated a final scenario with 18 buses, one for every order! And I was quite surprised that the algorithm only assigned orders to 5 of them. I ran all the other algorithms again, but always got the same results. With no other ideas on my mind, the only other way I can think of to solve this mistery is to contact Esri.

5 Annex

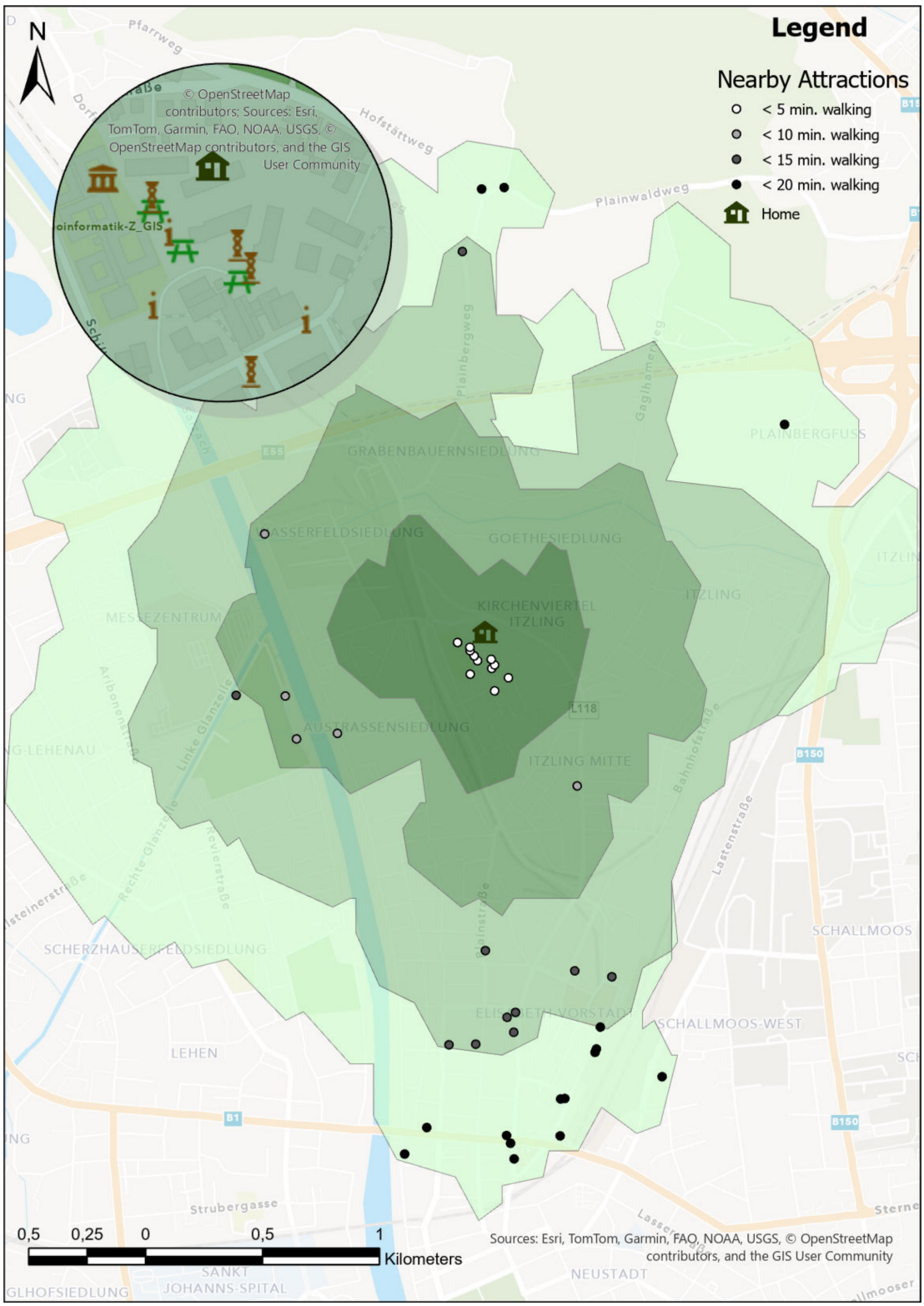

Figure 4: Map of Salzburg centered around my home. In various shades of green, from darkest to lightest, are the areas accessible by foot in 5, 10, 15, and 20 minutes, as calculated using OSM street data. The touristic attractions reachable within these areas are represented as dots. The small circular window on the top-left shows a detailed view of the area within a 5-minute walking distance, with the touristic attractions now represented as different symbols depending on their nature.

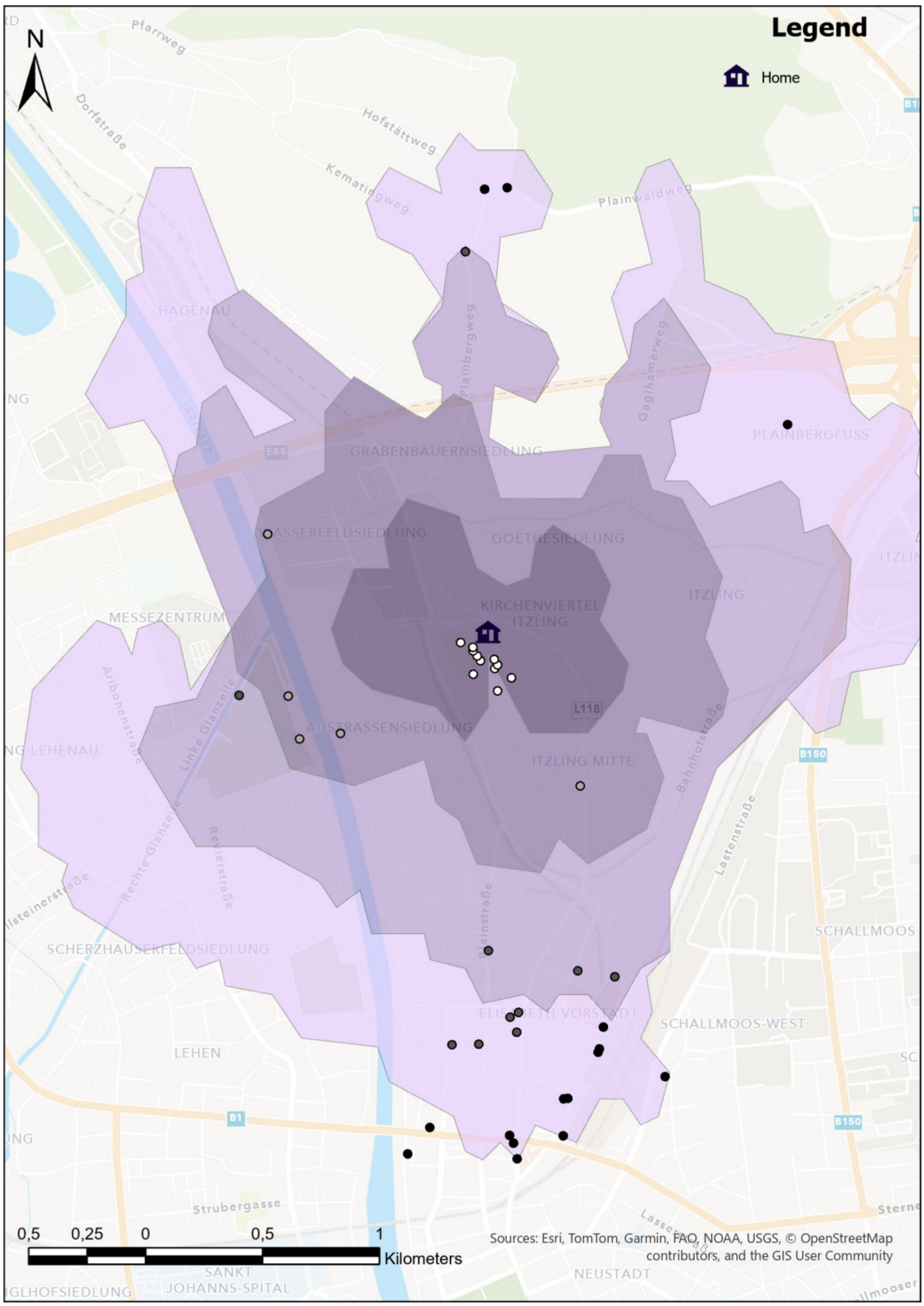

Figure 5: Map of Salzburg centered around my home. In various shades of purple, from darkest to lightest, are the areas accessible by foot in 5, 10, 15, and 20 minutes, as calculated using ArcGIS's own dataset. The touristic attractions reachable using OSM are plotted with the exact same colors to better compare the two maps. Notice that two attractions now fall completely outside the colored areas.