Urban Digital Twin Bologna

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1   Green Area

1.1   Gate Tagging

The goal of this step is to tag the road gates used in the simulation using qualitative information obtained from the analysis of Bologna's open data. The process will proceed as follows:

1. Selection of qualitative indices

2. Recreation of qualitative indices via code

3. Classification of qualitative indices (5 portions)

4. Association of indices to gates

5. Alignment of the simulator code

6. Alignment of the `dashboard.py` code

7. Separate analysis of the results of the variables with associated graphs

8. Analysis of the results of the variables simultaneously

1.1.1   Selection of qualitative indices

The selection of qualitative indices is inspired by the Gender Maps [4] produced by the Municipality of Bologna in 2022. The **statistical area** is the level of aggregation on which the indicators will be calculated. The reference dataset is `aree-statistiche` [1].

Female-to-male population balance indicator

The first indicator we analyze is the balance of the female population compared to the male population. This indicator is obtained from the dataset `popolazione-residente-per-eta-sesso-cittadinanza-quartiere-zona-area-statistica-` [5] and is calculated as:

$$\frac{Female\ residents}{Male\ residents}$$

Obs	Mean	Std. dev	Min	Max
91	1.049121	0.2818969	0.19	2.65

There are 91 observations, one more than the number of statistical areas. This is because the demographic datasets include statistical area 99, which refers to people without fixed abode. This area will be excluded as it does not impact the vehicle flow analysis. Note also how the *minimum* and *maximum* are quite far from the mean, meaning there are areas with a significant gender imbalance.

Analyzing these cases together with the dataset `indici-di-fragilita-dal-2021` [2], it is evident that some statistical areas are not residential zones and are excluded from fragility index analyses, specifically those with fewer than 150 inhabitants. The dataset contains the flag `flag-area-esclusa`, which is set to 1 for the following areas:

Code AS	Statistical Area	Females	Males	Female/Male Balance
3	BARGELLINO	35	40	0.88
6	LUNGO RENO	4	40	0.4
13	CNR	21	29	0.72
42	FIERA	6	16	0.38
46	SCALO MERCI SAN DONATO	12	30	0.4
55	GIARDINI MARGHERITA	21	12	1.75
66	OSPEDALE SANT'ORSOLA	53	20	2.65
75	VIA DEL GENIO	8	7	1.14
86	OSPEDALE BELLARIA	70	46	1.52

Excluding these codes from our analysis we get the following distribution:

Obs	Mean	Std. dev	Min	Max
81	1.054815	0.1457662	0.43	1.23

Below is the Stata code used to process the data:

```
import delimited "/Users/venere/Downloads/popolazione-residente-per-eta-sesso-cittadinanza
-quartiere-zona-area-statistica- (3).csv", clear
collapse (sum) residenti, by(codiceareastatistica anno sesso)
reshape wide residenti, i(codiceareastatistica) j(sesso) string
gen rapporto_mf = residentiFemmine / residentiMaschi
gen rapporto_mf_round = round(rapporto_mf, 0.01)
sum rapporto_mf_round
drop if inlist(codiceareastatistica, 3,6,13,42,46,55,66,75,86,99)
sum rapporto_mf_round
```

We now assign each statistical area a score that qualitatively indicates the gender ratio based on the intervals defined in the Gender Maps [4].

Interval	Score
<0.5	-4
0.5 - 0.64	-3
0.64 - 0.79	-2
0.79 - 0.93	-1
0.93 - 1.07	0
1.07 - 1.21	1
1.21 - 1.36	2
1.36 - 1.5	3
>1.5	4

Economic fragility indicator

The second index analyzed is the economic fragility indicator. Fragility is analyzed across three domains: demographic, social, and economic. For each domain, a synthetic indicator is calculated using a normalization process, which assigns scores to analytical indicators, followed by aggregation. These indicators are comparable over time. Areas with a fragility level above the reference value have indicator values greater than 100; those below have values under 100. The reference value corresponds to Bologna's citywide indicators for 2020–2022 (??). Thus, this measures both the potential risk of fragility in the area and how it has changed compared to the previous three-year period.

How does this differ from the single fragility index [3]?

We select the economic fragility index available in the dataset `indici -di-fragilita-dal-2021` [2].

Its distribution is as follows:

Obs	Mean	Std. dev	Min	Max
81	97.58025	7.524733	81	120

Stata code used for processing:

```
import delimited "/Users/venere/Downloads/indici-di-fragilita-dal-2021-2.csv",
clear (encoding automatically selected: UTF-8) (30 vars, 90 obs)
keep codareastatistica indicepotenzialefragilitàeconomi flagareaesclusa
drop if flagareaesclusa == 1
(9 observations deleted)
sum indicepotenzialefragilitàeconomi
```

Now, we assign each statistical area a score ranging from Low to High fragility, dividing the range into 5 subintervals:

Interval	Score	Economic Fragility
81.0 - 89	1	Low
89 - 97	2	Medium-Low
97 - 105	3	Medium
105 - 113	4	Medium-High
113 - 120	5	High

1.1.2 Association of indices to gates

The purpose of this section is to assign each gate a score based on the statistical area it belongs to, referencing the previously mentioned indicators.
Currently, the vehicle flow information is aggregated by *zones*, which are manually defined and do not exactly match Bologna's statistical areas. Therefore, we will map the *zones* and *statistical areas* geographically. The relationship is $n : m$.

```
gdf_area_verde = gpd.read_file("/Users/venere/Documents/GitHub/AreaVerde/Simulation/area_verde_manual_v1.geojson")
aree_gdf_inside = gpd.read_file("/Users/venere/Documents/GitHub/AreaVerde/Simulation/aree_gdf_inside_v2.geojson")
aree_gdf_outside = gpd.read_file("/Users/venere/Documents/GitHub/AreaVerde/Simulation/aree_gdf_outside_v2.geojson")
aree_gdf = pd.concat([aree_gdf_inside, aree_gdf_outside], axis=0)
aree_gdf_AV = gpd.overlay(aree_gdf, gdf_area_verde, how='intersection')
aree_statistiche = gpd.read_file("/Users/venere/Documents/GitHub/AreaVerde/Simulation/aree-statistiche.geojson")
aree_e_areastatistica_gdf_AV = gpd.overlay(aree_gdf_AV, aree_statistiche, how='intersection')
```

As noted earlier, each zone is associated with more than one statistical area and vice versa. To assign each zone a representative score, we compute a weighted average of the statistical areas' values, using population as weights.
    explanation

References

[1]   Comune di Bologna. *aree-statistiche*. URL: https://opendata.comune.bologna.it/explore/dataset/aree-statistiche/information/ (visited on 04/16/2025).

[2]   Comune di Bologna. *indici-di-fragilita-dal-2021*. URL: https://opendata.comune.bologna.it/explore/dataset/indici-di-fragilita-dal-2021/information/?disjunctive.area_statistica (visited on 04/16/2025).

[3]   Comune di Bologna. *la-fragilita-demografica-sociale-ed-economica-nelle-diverse-aree-del-comune-di-Bologna*. URL: https://inumeridibolognametropolitana.it/studi-e-ricerche/la-fragilita-demografica-sociale-ed-economica-nelle-diverse-aree-del-comune-di (visited on 04/16/2025).

[4]   Comune di Bologna. *Mappe di Genere*. 2022. URL: https://inumeridibolognametropolitana.it/notizie/mappe-di-genere-strumenti-informare-e-orientare-le-politiche-della-citta (visited on 04/16/2025).

[5]   Comune di Bologna. *popolazione-residente-per-eta-sesso-cittadinanza-quartiere-zona-area-statistica-*. URL: https://opendata.comune.bologna.it/explore/dataset/popolazione-residente-per-eta-sesso-cittadinanza-quartiere-zona-area-statistica-/information/?disjunctive.area_statistica&disjunctive.quartiere&disjunctive.zona&disjunctive.sesso&disjunctive.eta_grandi&disjunctive.eta&disjunctive.cittadinanza (visited on 04/16/2025).