Annex to the paper "Pecoraro, F., Accordino, F., Cecconi, F., Paolucci, M.: ABM for simulating the access to elective surgery services: the issue of patient mobility in Italy. Submitted to the 18th Social Simulation Conference, Glasgow, Scotland, 4th-8th September 2023".

This Annex describes in details the steps of the methodology for computing the accessibility indices adopted in the theoretical framework of [1]. The methodology has been introduced in our previous papers [2,3] to determine the level of accessibility of each patient to both intra and interregional resources. It adopted the gravity model to determine the probability that a patient accesses to a hospital based on hospital's capacity (e.g., number of beds, number of interventions performed) and (travel) distance. Considering, for instance, the distribution of the number of interventions (int_j) yearly performed by the hospital *j*, the accessibility index of the municipality *i* (INT_i) is computed as follows adopting the enhanced two step floating catchment area methodology (E2SFCA) [4] (see Equation 1).

$$INT_i = \sum_j int_j w_{i,j} R_j \tag{1}$$

Where:

- $w_{i,j}$ represents the weighting distance between the hospital *j* and the municipality *i* computed using the Sigmoid decay function (see Equation 2) so that $w_{i,j} = 1$ if $d_{i,j} = 0$ and $w_{i,j} = 0$ if $d_{i,j} \geq d_{max}$.

$$w_{i,j} = e^{-\frac{0.1\, {d_{i,j}}^2}{2\, d_{max}^2}} \tag{2}$$

- $d_{i,j}$ represents the distance in minutes between the municipality of the patient *i* and the municipality of the hospital *j*. Driving distances have been obtained from a distance matrix published by the Italian National Institute of Statistics (ISTAT). ISTAT calculates the driving distance between centroids for all Italian municipalities in 2013 using a commercial road graph [5].
- d_{max} represents the maximum patient-hospital catchment area to determine the maximum distance a patient is willing to travel for accessing to a care service. As reported in the following this parameter is based on a set of socio-economic features.
- R_j denotes the weighted hospital-to-population ratio computed considering the population (pop_i) of all municipalities *i* within the hospital catchment area and based on the weighting distance $w_{i,j}$. To simplify its readability this index has been computed based on 10^5 inhabitants.

$$R_j = \frac{10^5}{\sum_i pop_i * w_{i,j}} \tag{3}$$

Intra and interregional components of INT_i can be further computed considering the interventions performed by hospitals located within or outside the region of the municipality *i* (see Equation 4).

$$\begin{cases} INT_i^{intra} = \sum_{j \in \{Reg(i) = Reg(j)\}} INT_j R_j w_{i,j} \\ INT_i^{inter} = \sum_{j \in \{Reg(i) \neq Reg(j)\}} INT_j R_j w_{i,j} \end{cases} \tag{4}$$

Where:

- INT_i^{intra} represents the intra-regional component of the accessibility index computed considering the hospitals located in a municipality (j) that belongs to the same region (*Reg(j)*) of the patient's municipality (*Reg(i)*).
- INT_i^{inter} represents the inter-regional component of the accessibility index computed considering the hospitals located in a municipality (*j*) outside the patient's region of residence (*Reg(j)*).

An average of each index weighted by population can be computed at province and regional level to provide an aggregated value of the accessibility index

Concerning the willingness to travel of patients, we identity a set of individual socio-economic features that have a strong impact on the opportunity of patients to move from their place of residence to access to care services [6-8]. In our model we adopt them to compute the maximum patient-hospital catchment area (d_{max}, see Equation 2) taking into account three conditions:

1. age lower than 65 years,
2. having a secondary education and
3. income higher than 18k Euros/year.

The maximum distance is computed as $d_{max} = \frac{2^n}{4}\sigma$, where σ represents the standard deviation computed over the distances between the patient and the hospitals and n represents the number of conditions met, so that a patient that met all the conditions has $d_{max} = 2\sigma$, while a patient who does not met any condition has $d_{max} = \frac{\sigma}{4}$.

d_{max} has been adopted to compute the weighting distance ($w_{i,j}$, see Equation 2).

Note that for this study [1], data have been gathered from the Ministry of Health [9], the Italian Institute of Statistics (ISTAT) [10] and the Italian National Outcomes Programme (Programma Nazionale Esiti, PNE) [11]. All data refers to the year 2019. Moreover, islands were excluded from the analysis as residents cannot access to interregional facilities by car.

References

1. Pecoraro, F., Accordino, F., Cecconi, F., Paolucci, M.: ABM for simulating the access to elective surgery services: the issue of patient mobility in Italy. Submitted to the 18th Social Simulation Conference, Glasgow, Scotland, 4th-8th September 2023
2. Pecoraro, F., Luzi, D., Clemente, F.: The impact of Hospital accessibility on interregional patient mobility in Italy. Stud Health Technol Inform 294, 684–688 (2022).
3. Pecoraro, F., Luzi, D., Clemente, F.: Spatial Inequity in Access to Intensive Care Unit Beds at Regional Level in Italy. Stud Health Technol Inform 281,809-813, 2021.
4. Luo, W., Qi, Y.: An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians. Health Place 15, 1100–7, 2009.
5. Italian National Institute of Statistics (ISTAT). Matrici di contiguità, distanza e pendolarismo (Contiguity, distance and commuting matrices), https://www.istat.it/it/archivio/157423
6. Nante, N., Guarducci, G., Lorenzini, C., Messina, G., Carle, F., Carbone, S., Urbani, A.: Inter-Regional Hospital Patients' Mobility in Italy. Healthcare 9(9), 1182 (2021).
7. Rubino, C., Di Maria, C., Abbruzzo, A., Ferrante, M.: Socio-economic inequality, interregional mobility and mortality among cancer patients: A mediation analysis approach. Socio-Economic Planning Sciences 82, 101247, 2022.
8. Balia, S., Brau, R., Marrocu, E.: Interregional patient mobility in a decentralized healthcare system. Regional Studies 52(3), 388-402, 2018.
9. Ministry of Health. National healthcare service database. 2019, www.salute.gov.it/portale/documentazione/p6_2_8_1_1.jsp?lingua=italiano&id=6.
10. Italian National Institute of Statistics (ISTAT), http://dati.istat.it/?lang=en.
11. Italian National Outcomes Programme (PNE), https://pne.agenas.it/.