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OASES

Promoting evidence-based reforms on medical deserts

D4.1-
A potential spatial access measure tool package

31/08/2022

Co-funded by
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OASES Promoting evidence-based reforms on medical deserts

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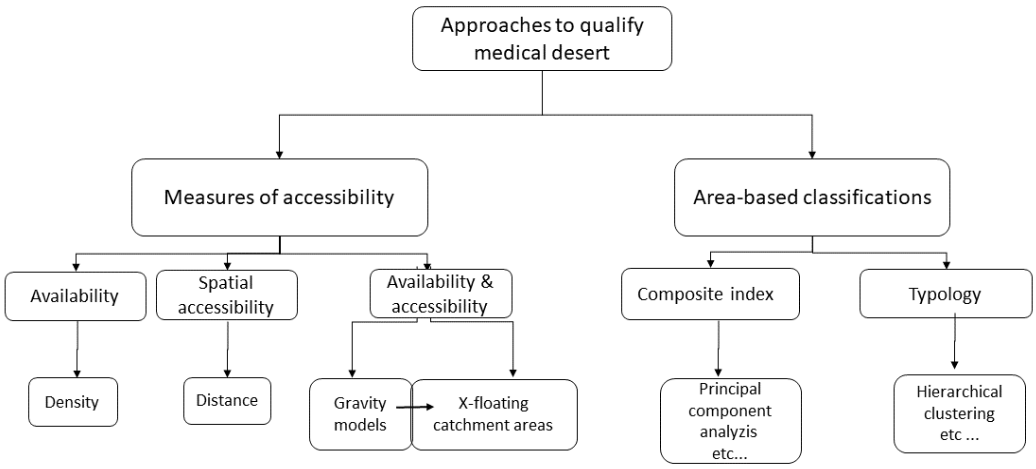
Introduction

The expression "medical desert" is commonly used in the public and mediatic field referring to several situations or areas where people have difficulties to access care. The identification of such areas is a major challenge because 'the greatest obstacle to the application of the concept of accessibility lies in the difficulty of translating it in the form of operational indicators' (Handy and Niemer, 1997). This is exacerbated by the fact that the accessibility itself is complex to address due to its multidimensional nature (spatial, physical, temporal, financial and cultural) (Penchansky and Thomas, 1981; Russel, 2013).

Aware of that, we assume there are several ways to qualify medical deserts, but we identify two complementary approaches that seem particularly relevant (figure 1): (1) developing accurate index of accessibility and (2) describing places with several indicators through classifications.

Figure 1 - Propositions of approaches to qualify medical deserts



The objective of this report corresponds to the Deliverable 4.1 of the OASES project. It aims at sharing to the other countries a tool package in order to qualify medical desert.

The pedagogical support provided to the partners is of different types. This includes, on the one hand, online support (documents made available on the OASES Project Hub that can be used throughout the project by the countries) and, on the other hand, webinars and bilateral meetings to explain and discuss the methods.

This document brings together the elements provided to address both approaches. It is divided into two parts, one dealing with accessibility indicators and the other with spatial approaches to describe medical deserts with several dimensions.

1 Spatial accessibility indicators

1.1 Introduction of different measures of the spatial accessibility

This dissemination focuses on potential spatial access, which refers to the ease with which residents of a given area can reach services and facilities (Apparicio and al., 2008).

Four types of approaches to defining accessibility have been identified in the literature (Geurs and Van Wee 2004).

I) The first is to measure the efficiency of transport networks with indicators of traffic congestion and average travel speed, for example.
II) The second approach is place-based measures in which the level of accessibility is associated with a place or spatial unit of analysis, which defines accessibility in terms of the physical separation between the location of desired services and key locations in daily life such as the place of residence or the place of work.
III) The third is individual-centered measures. Based on the concepts of Time-geography (Hägerstrand 1970), this other type of measure expresses accessibility on the basis of detailed observations of the spatio-temporal constraints of individuals. In contrast to the first approach, it takes into account individual trajectories by defining time-locks that indicate when, where and for how long an individual can access a place. This type of measure has been developed in geographic information system and is widely used in activity-based-approach when studying mobilities according to spatial and temporal constraints. The disadvantage of these measures is related to the complexity of their implementation, as they require access to data representative of the daily activities of a sample of individuals, which are most often unavailable.
IV) The last approach is based on utility. Accessibility is captured in terms of the benefit that individuals derive from access to services by calculating the probability that an individual will make a particular choice based on the relative utility that he or she attributes to that choice compared to all other possible choices.

Place-based measures are generally preferred when used to measure levels of accessibility because they inform governments and land-use planners about areas with accessibility deficits and allow for the assessment of socio-spatial inequalities (Apparicio and al. 2008). There are several ways to define place-based measures of accessibility to care: measuring the relationship between a supply of care and a population group and measuring the distance to the supply for an individual or population (Luo and Wang 2003, Ricketts 2010). The five most common measures of the accessibility of health services associated with them are:

> (1) population-to-provider ratios (PPR) (2) the distance to the closest service; (3) the number of services within n meters/km or minutes or the mean distance to the n closest services; (4) gravity models combining availability and proximity; and (5) x-floating catchment area (xSFCA) indicators which are more sophisticated measures of access than previous measures indicators derived from gravity model.

Density indicators are very commonly used. They have the advantage of being easy to calculate and intuitive for professionals and decision-makers, and mobilize readily available data. Health care supply ratios (densities) are traditionally used in international comparisons of health care systems to highlight differences in staffing between countries (European Observatory on Health Systems and Policies 2020; OECD 2016) or within countries to measure disparities in staffing at different scales.

Distance is a simple and commonly used measure of proximity to care (Fortney and al. 2000, Rosero-Bixby 2004). In particular, it is recognized as a good measure of spatial accessibility in rural areas, because the choice in terms of care offer is limited and the closest offer is the one that has the highest probability of being used. On the other hand, consulting a care offer that is not the closest to the place of residence is also frequently observed when the quantity of care offers available in the patient's environment allows it to be chosen (Goodman and al. 2003, Hyndman and al. 2003). An alternative solution is not to consider the immediate proximity but the average distance to the services, i.e. the distance between a place and several locations within a defined perimeter, which makes it possible to relativize the finding established with the immediate proximity. The distance of access to the nearest service is nonetheless a relevant indicator for highlighting the thresholds beyond which access to a specialty, a hospital discipline or a heavy facility becomes difficult. This distance thus makes it possible to locate populations that live far from care. It is a good indicator of the performance of resource allocation in a given territory, because controlling and reducing distance is a permanent concern in the planning of health care provision in particular for certain services such as primary care or certain hospital services (maternity, orthopedics, etc.). The development of geographic information systems (GIS) has made it possible to improve the measurement of distances, from Euclidean distances (as the crow flies) to travel time distances according to the mode of transportation used (on foot, by car, by bicycle, or by public transit). The most commonly used is the distance by car because of availability of data. Distances are measured in time rather than kilometers since they take into account a number of parameters such as topography, network configuration and network operation.

The indicator of xSFCA method is a fairly recent one focusing on the spatial interaction of providers and populations with gravity models. It was proposed in 2003 by Luo and Wang (2003) based on the work of Radke and Mu (Radke 2000). This type of indicators models the potential spatial interaction between supply and demand and focuses on how distance affects the attraction of a supply or service. This type of measurement makes it possible to overcome several limitations related to the density and distance indicators. For density, the fundamental limitations are that it refers only to the availability of health care in a given area and implicitly assumes that the service or professional located just across the boundary of the area will not be accessible. It thus ignores population movements across administrative boundaries, even though these are frequent, especially when density is measured for small areas. Distance, on the other hand, ignores geographic boundaries but does not take into account the quantity of supply in a given location.

The principle of the xSFCA is to take into account the supply of care and demand in the geographical unit under consideration, but also that of the surrounding geographical units. Thus, applied at the municipal level for General Practitioners (GPs) for example, this indicator considers that the inhabitants of a municipality have access to the supply in their municipality but also to all GPs located in the surrounding municipalities up to a certain distance. At the same time, each GP potentially responds to the demand of all the inhabitants of the municipalities located up to a certain distance from the practice.

The computation of the first measure (2SFCA) consists of two steps: (i) determining the population that falls within the catchment of each health care provider to compute the provider-to-population ratio, and (ii) allocating providers to populations by determining which providers fall within the catchment of each population and sum up the population-to-provider ratios obtained in the first step of the procedure.

Since its introduction, many authors have suggested improvements to the basic model (2SFCA indicator) concerning:

1. distance decay effects (Luo and Qi, 2009) to introduce a decreasing probability of care use as a function of distance (named E2SFCA);
2. the incorporation of variable catchment sizes (McGrail and Humphreys, 2009; 2014) between types of spaces (urban vs rural) for example;
3. multiple transport modes (Mao and Nekorchuk, 2013) not to consider only car mode (MM2SFCA);
4. effect of relative position of supply (Wan et al., 2012) (3SFCA): The 2SFCA admits or rather assumes that people do not consult a doctor too far from home and that they prefer the various services available nearby. The 3SFCA starts from the same assumption but qualifies it: individuals prefer proximity, especially when a local offer is accessible and available;
5. adjusted health care demand on age (Ngui and Apparicio, 2011);
6. adjusted health care supply using level of activity of health professionals (Barlet et al. 2012) rather than effectives (LPA indicator) but alternatively we consider that active file could be another good indicator;
7. adjusted health care demand by age and social dimension with LPA indicator (Lucas-Gabrielli and Mangeney 2019).

1.2 Reading guide

We highly recommend reading the following references. They contain a selection of key articles on calculation methods, results obtained in different contexts and related discussions.

1) Potential/Spatial healthcare access literature review

Neutens T. (2015). Accessibility, equity and health care: review and research directions for transport geographers. Journal of Transport Geography. 43: 14-27.

Fortney J., Rost K. et Warren J. (2000). Comparing Alternative Methods of Measuring Geographic Access to Health Services, Health Services and Outcomes Research Methodology. 1(2): 173-184.

Ricketts T. (2010). Accessing health care. A Companion to Health and Medical Geography. M. S. Brown T., Moon G. Willey-Blackwell.

2) Presentation of x-SFCA method

Barlet M., Coldefy M., Collin C., Lucas-Gabrielli V. (2012). "Local Potential Accessibility (LPA): A new measure of accessibility to private General Practitioners”. QES 174.

Donohoe J., Marshall V., Tan X., Camacho F., Anderson R., Balkrishnan R. (2016). "Spatial access to primary care providers in Appalachia: Evaluating current methodology". Journal of Primary Care and Community Health, Vol. 7(3) 149–158.

Langford M., Higgs G., (2016). "Multi-modal two-step floating catchment area analysis of primary health care accessibility". Health and Place 38: 70-81.

Lucas-Gabrielli V. and Mangeney C. (2019). "How can the methods for measuring the spatial inequalities of access to general Inequalities of access to general practitioners be improved? Illustration in Ile-de-France". QES n°246 (+ a more detailed working paper in the OASES project hub).

Luo W. (2004). Using a GIS-based floating catchment method to assess areas with shortage of physicians. Health and Place. 10(1): 1-11.

Luo W. et Qi Y. (2009). "An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians". Health and Place 15: 1100-1107.

Luo, J. (2014). "Analyzing Spatial Access to Healthcare Services".Transactions in GIS, 18: 436-448.

Mao L. et Nekorchuk D. (2013). "Measuring spatial accessibility to healthcare for populations with multiple transportation modes". Health and Place 24: 115-122.

McGrail M., Humphreys J.S. (2009a). "The index of rural access: an innovative integrated approach for measuring primary care access". BMC health services research.

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McGrail M., Humphreys J.S., (2014). "Measuring spatial accessibility to primary health care services: utilising dynamic catchment sizes". Applied Geography 54, 182-188.

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Siegel M., Koller D., Vogt V., Sundmacher L. (2016). "Developing a composite index of spatial accessibility across different health care sectors: a German example". Health Policy 120(2): 205-212.

Subal J., Paal P., Krisp J. (2021). "Quantifying spatial accessibility of general practitioners by applying a modified huff three-step floating catchment area (MH3SFCA) method". International Journal of Health Geographics 20(1):9.

Wan N., Zou B., Sterngerg T. (2012). "A 3-step floating catchment area method for analyzing spatial access to health services". International journal of geographical information science, 26:6, 1073-1089.

Wang F. (2012). "Measurement, optimization and impact of health care accessibility: A methodological review". Annals of the Association of American Geographers, 102(5), 1104–1112.

Extensive bibliography:

Apparicio P., Abdelmajid M., Riva M., Shearmur R. (2008). "Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues". International Journal of Health Geographics 7(1): 7.

European Observatory on Health Systems and Policies (2020). Health system reviews (HiT series).

Fortney J., Rost K. et Warren J. (2000). “Comparing Alternative Methods of Measuring Geographic Access to Health Services”. Health Services and Outcomes Research Methodology. 1(2): 173-184.

Gao F., Languille C., Karzari K., Guhl M. Boukebous B., Deguen S. (2021). “Efficiency of fine scale and spatial regresions in modelling associations between healthcare service spatial accessibility and their utilization”. International Journal of Health Geographics, 20: 22.

Geurs, K.T., Van Wee, B. (2004). “Accessibility evaluation of land-use and transport strategies: review and research directions”. Journal of Transport Geography, 12(2), 127–140.

Goodman D. C., Mick S. S., Bott D., Stukel T., Chang C., Marth N., Poage J. et Carretta H. J. (2003). “Primary Care Service Areas: A New Tool for the Evaluation of Primary Care Services”. Health Services Research. 38(1 Pt 1): 287-309.

Handy S. L., Niemer D. A. (1997). "Measuring accessibility: An exploration of issues and alternatives". Environment and Planning A 29 1175-1194.

Hägerstrand, T. (1970). “What about people in regional?”. Regional Science Association Papers XXIV.

Hyndman J. C., Holman C. D. et Pritchard D.A. (2003). “The influence of attractiveness factors and distance to general practice surgeries by level of social disadvantage and global access in Perth, Western Australia”. Social Science and Medicine. 56(2): 387-403

Luo W. et Wang F. (2003). “Measures of spatial accessibility to health care in a GIS environment: Synthesis and a case study in the Chicago region”. Environment and Planning B: Planning and Design. 30(6): 865-884

OECD (2016). ”Health Workforce Policies in OECD Countries: Right Jobs, Right Skills, Right Places” http://dx.doi.org/10.1787/9789264239517-en.

Penchansky, R., & Thomas, J. W. (1981). The concept of access: definition and relationship to consumer satisfaction. Medical care, 127-140.

Radke J. et Mu L. (2000). “Spatial decompositions, modeling and mapping service regions to predict access to social programs“. Geographic information sciences 6(2).

Rosero-Bixby L. (2004). “Spatial access to health care in Costa Rica and its equity: A GIS-based study”. Social Science and Medicine. 58 (7): 1271-1284.

Russell DJ., Humphreys JS., Ward B., Chisholm M., Buykx P., McGrail M., Wakerman J. (2013). “Helping policymakers address rural health access problems”. Aust Journal of Rural Health.

1.3 Scripts and examples of data sets

In this sub-section, programs codes in SAS are proposed to help countries construct the main accessibility indicators presented above. The codes contain explanatory material to make it easier to understand each step of the calculation and are accompanied by example data sets (first lines for each example). Programs in SAS, a Python version and example datasets are also available for countries on the OASES Project Hub. Those programming languages were chosen because they are commonly used.

To construct the indicators, it is imperative to start with the "Data importation" section and then to run the indicator code(s) that interest us. The three have been designed to work separately.

It should also be noted that copying the lines of code from the report directly into a SAS program can be risky because the report format is not a notebook and ASCII code could pollute the result. You should therefore remain cautious and if possible, use the versions directly in the format .sas or .ipynb available on the OASES Project Hub.

1.3.1 Data importation

```
/*******************************************************************************
                    Data Importation and preparation

There are in general three types of data to be imported:
1. Supply data -> health service data of each supply geographical unit (destination)
2. Demand data -> population data of each demand geographical unit (origin)
3. Distance matrix -> distance or travel time from each demand geographical unit (origin) to supply geographical unit (destination)
*******************************************************************************/
/** First, we create a directory in which the final tables will be saved **/

libname oases '/OASES/DATA/';

/*******************************************************************************
                    Step 1: Supply data

Each line represents a GPs number of a supply geographical unit (destination)
```

Table 1 : GPs_2021 (supply data)

	Code	GPs_number
1	59001	0
2	59002	2
3	59003	0
4	59004	0
5	59005	2

```
*******************************************************************************/
proc import datafile="/OASES/DATA/GPs_2021.csv"
   out=WORK.GPs_2021   /* name of the output table*/
   dbms=csv            /* type of data to import */
   replace;            /* to replace the output table */
   delimiter=';';      /* The separator used */
```

```
 getnames=yes;
run;

/****************************************************************************
```

Step 2: Demand data

Each line represents a population volume of a demand geographical unit (origin)

Table 2: pop_2018_Nord (demand

	CODGEO	pop_total
1	59001	469
2	59002	4376
3	59003	369
4	59004	1275
5	59005	3458

```
****************************************************************************/
proc import datafile="/OASES/DATA/pop_2018_Nord.csv"
   out=WORK.pop_2018_Nord
   dbms=csv
   replace;
   delimiter=',';
   getnames=yes;
run;
/****************************************************************************
```

Step 3: Distance matrix

Each line represents a distance between demand geographical unit (origin) and offer geographical unit (destination)

We chose to use the average travel time in minutes between off-peak and peak hours to measure the distance between supply and demand

Table 3: Nord_distance (distance matrix)

	COM_ORIGIN	COM_DESTIN	Time
1	59163	59163	0
2	59163	59512	10
3	59163	59646	12
4	59163	59421	14.5
5	59163	59299	17

```
****************************************************************************/
proc import datafile="/OASES/DATA/Nord_distance.csv"
   out=WORK.Nord_distance
   dbms=csv
   replace;
   delimiter=',';
   getnames=yes;
run;

/** Step 4: Join three types of data (see table in annex 2, table 1) **/

PROC SQL;
  CREATE TABLE WORK.Data_tmps AS
  SELECT put(t1.COM_ORIGIN, 5.) as COM_ORIGIN,
                    put(t1.COM_DESTIN, 5.) as COM_DESTIN,
       t1.Time,
       t2.GPs_number AS Sj,
```

```
 t3.pop_total
    FROM WORK.NORD_DISTANCE t1
        LEFT JOIN WORK.POP_2018_NORD t3 ON (t1.COM_ORIGIN = t3.CODGEO)
        LEFT JOIN WORK.GPS_2021 t2 ON (t1.COM_DESTIN = t2.Code)
    ORDER BY t1.COM_ORIGIN,
            t1.COM_DESTIN;
QUIT;

/*******************************************************************************
```

Step 4: Creation of new weight variable depending on the travel time

Referring to the literature review and previous work in France (DREES), we decide to assign a value of:
1 -> if the travel is less than 10 min
0.667 -> if the travel time is between 10 and 15 min
0.33 -> if the travel is between 15 and 20min
0 -> if the travel is more than 20min

```
*******************************************************************************/
PROC SQL;
  CREATE TABLE oases.DATA_FINAL AS
  SELECT t1.COM_ORIGIN,
       t1.COM_DESTIN,
       t1.Time,
       t1.Sj,
       t1.pop_total,
       /* Creation of the variable wij */
        (CASE
          WHEN t1.Time >= 0 AND t1.Time <= 10 THEN 1
          WHEN t1.Time >= 10.00000000001 AND t1.Time <= 15 THEN 0.667
          WHEN t1.Time >= 15.00000000001 AND t1.Time <= 20 THEN 0.333
          ELSE 0
        END) AS wij
    FROM WORK.DATA_TMPS t1
    WHERE t1.COM_ORIGIN LIKE '59%' AND t1.COM_DESTIN LIKE '59%';
QUIT;

;*';*";*/;quit;run;
ODS _ALL_ CLOSE;
/*******************************************************************************
```

Table 5: Data_final (results of the step 5)

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij
1	59001	59001	0	0	469	1
2	59001	59002	26	2	469	0
3	59001	59004	50	0	469	0
4	59001	59005	59.5	2	469	0
5	59001	59006	37	0	469	0

```
*******************************************************************************/
```

1.3.2 Distributed density

```
/*****************************************************************************
Step 1: Catchment definition

1.1 : Assign to the distance matrix the population of COM_DESTIN (POP_DES). Pay attention that "POP_Total" is the population of COM_ORIGIN (see table annex 2, table 2)

*****************************************************************************/
libname oases '/OASES/DATA/';

proc import datafile="/OASES/DATA/pop_2018_Nord.csv"
   out=WORK.pop_2018_Nord
   dbms=csv
   replace;
   delimiter=',';
   getnames=yes;
run;

PROC SQL;
  CREATE TABLE WORK.data_final_pop_des AS
  SELECT t1.*,
  t2.pop_total as POP_DES
    FROM oases.data_final t1
       LEFT JOIN WORK.POP_2018_NORD t2 ON (t1.COM_DESTIN = put(t2.CODGEO, 5.))
    ORDER BY t1.COM_ORIGIN,
          t1.COM_DESTIN;
QUIT;

/** 1.2: Select the catchment for each demand geographical unit (COM_ORIGIN) (see annex 2, table 3) **/

PROC SQL;
  CREATE TABLE work.data_tmp AS
  SELECT t1.*,
       /* Creation of Mij */
        (CASE
          WHEN t1.time > 10 THEN 0
          ELSE 1
        END) AS Mij
    FROM data_final_pop_des t1
          where calculated Mij=1
    ;
QUIT;
```

```
/*******************************************************************************
Step 2: Catchment definition

Calculate the distributed density by dividing all supply (sum (SJ)) by the population volume (sum (POP_DES)) in the catchment of each demand geographical unit (COM_ORIGIN) (see annex 2, table 4)
*******************************************************************************/

PROC SQL;

  CREATE TABLE WORK.dml AS
   SELECT COM_ORIGIN, sum(Sj) as sj_sum, sum(POP_DES) as pi_sum,
(sum(Sj)/sum(POP_DES))*100000 as DD
      FROM WORK.data_tmp t1
            group by COM_ORIGIN ;
QUIT;

;*';*";*/;quit;run;
ODS _ALL_ CLOSE;

/**Export of the indicator**/

PROC EXPORT DATA=WORK.dml
    DBMS=csv
    OUTFILE="/OASES/DATA/Distributed_density.csv"
    REPLACE;
 DELIMITER=";";
run;
```

1.3.3 2SFCA indicator

```
/*******************************************************************************
Step 1 : Supply ratio calculation

1.1: For each supply geographical unit (COM_DESTIN), calculate the population volume who might be subject to use its health service supply (Sum_Pop). The demand population volume depending on the distance weight (see annex 2, table 5).

/*******************************************************************************

libname oases '/OASES/DATA/';

proc sql;
create table Sum_Population as
select a.COM_DESTIN,
sum(Pop_total*Wij) as Sum_pop
from oases.data_final a
group by a.COM_DESTIN;
quit;

/**1.2: From the distance matrix, select the number of supply available for each supply geographical unit (COM_DESTIN) (see annex 2, table 6) **/
                    proc sql;
```

```
                    create table Cd_supply as
                              select distinct COM_DESTIN, Sj
                    from oases.data_final s;
          quit;

/**1.3 : join the variable "Sum_Pop" with the distance matrix, with each geographical supply unit (COM_DESTIN). Then calculate the supply unit ratio, by dividing the number of supplies by demand population (see annex 2, table 7) **/

proc sql;
create table ratio as
select s.*,d.*, sj/Sum_pop as ratio_cd
from Cd_supply s, Sum_Population d
where s.COM_DESTIN=d.COM_DESTIN;
quit;

/*******************************************************************************
Step 2: accessibility indicator calculation

 2.1 : Join the variable "ratio" with the distance matrix, with each geographical demand unit (COM_ORIGIN) (see annex 2, table 8)
*******************************************************************************/
proc sql;
create table matrice_ratio as
select  m.*, r.ratio_cd, r.Sum_pop
from ratio r, oases.data_final m
where r.COM_DESTIN=m.COM_DESTIN;
quit;

/** 2.2: For each demand geographical unit (COM_ORIGIN), summarize all supply ratios of the supply geographical units available. The ratio should be multiplied by the distance weight. This gives us a health service density indicator. In our case, number of GPs by 100 000 inhabitants (see annex 2, table 9) **/

proc sql;
create table two_SFCA as
select COM_ORIGIN, sum(ratio_cd * wij)*100000 as two_SFCA
from matrice_ratio m
group by m.COM_ORIGIN;
quit;

;*';*";*/;quit;run;
ODS _ALL_ CLOSE;

/** Export of the indicator**/

PROC EXPORT DATA=WORK.two_SFCA
   DBMS=csv
   OUTFILE="/OASES/DATA/TWO_SFCA_indicator.csv"
   REPLACE;
 DELIMITER=";";
run;
```

1.3.4 3SFCA indicator

```
/*********************************************************************************
Step 1 : Calculation of selection probability

1.1 : From the distance matrix, for each demand geographical unit (COM_ORIGIN), calculate all the health service supply available in the catchment (Sum_supply). The accessibility level depends on the distance weight Wji (see annex 2, table 10)
*********************************************************************************/
 libname oases '/OASES/DATA/';

proc sql;
create table Sum_supply as
select a.COM_ORIGIN,
sum(Sj*Wij) as Sum_supply
from oases.data_final a
group by COM_ORIGIN;
quit;

/** 1.2 : Join the variable "Sum_supply" with the distance matrix, with each geographical demand unit (COM_ORIGIN) (see annex 2, table 11)**/

proc sql;
create table data_final_Sum_supply as
select s.*,d.*
from oases.data_final s, Sum_supply d
where s.COM_ORIGIN=d.COM_ORIGIN;
quit;

/**1.3 : Calculate the selection probability of each supply geographical unit (COM_DESTIN) by each demand unit (see annex 2, table 12) **/

data data_final_Gij; set data_final_Sum_supply;
Gij = ((Sj*Wij)/Sum_supply);
run;

/*********************************************************************************
Step 2: Supply ratio calculation

2.1: For each supply geographical unit (COM_DESTIN), calculate the population volume who might be subject to use its health service offer (Sum_Population) (see annex 2, table 13). The demand population volume depending on the distance weight and the selection probability.
*********************************************************************************/

proc sql;
create table Sum_Pop as
select a.COM_DESTIN,
sum(Pop_total*Gij*Wij) as Sum_Population
```

```
from data_final_Gij a
group by COM_DESTIN;
quit;

/**2.2 : As in the 1.2 step, join the variable "Sum_Pop" with the distance matrix, with each geographical demand unit (COM_ORIGIN) (see annex 2, table 14)**/

proc sql;
create table data_final_Sum_Pop as
select s.*,d.*
from data_final_Gij s, Sum_Pop d
where s.COM_DESTIN = d.COM_DESTIN;
quit;

/**2.3: Calculate the supply unit ratio, by dividing the number of supply by demand population (see annex 2, table 15)**/

data data_final_Ratio; set data_final_Sum_Pop;
if Sum_Population = 0 then Rj = 0; /*handeling the division by 0*/
  else Rj = Sj/Sum_Population;
run;

/*******************************************************************************
Step 3: accessibility indicator calculation

3.1 : For each demand geographical unit (COM_ORIGIN), summarize all supply ratios of the supply geographical units available. The ratio should be multiplied by the selection probability and the distance weight. This gives us a health service density indicator (see annex 2, table 16). In our case, number of GPs by 100 000 inhabitants.
*******************************************************************************/
proc sql;
create table THREE_SFCA as
select a.COM_ORIGIN,
sum(Rj*Gij*Wij)*100000 as i3SFCA
from data_final_Ratio a
group by COM_ORIGIN;
quit;

/** Export of the indicator **/

PROC EXPORT DATA=WORK.THREE_SFCA
                DBMS=csv
                OUTFILE="/OASES//DATA/THREE_SFCA_indicator.csv"
                REPLACE;
                DELIMITER=";";
run;
```

2 Spatial approaches to describe medical deserts with several dimensions

The preceding indicators highlight medical deserts through areas defined by a lower accessibility to care. Here we propose a methodology to qualify medical deserts through several dimensions to understand factors that influence them by their specificities (urban / rural, socio-demographic characteristics, attractiveness etc.). In this context, using **composite index or spatial typologies** could help improve our understanding of factors that could explain the spatial distribution of medical desert. However, the complexity, diversity and multiplicity of factors that should be taken into account to describe the medical desert concept pose a challenge in terms of methodological approach.

2.1 Composite index

Indexes were generated using two approaches. One sophisticated approach to compare territories consists in using multiple factors grouped in defined dimensions. Indexes can be used to summarize the multiple factors of a dimension by areas of interest. The variables used to describe each dimension are summarized in scores. The advantage is to have an index which describes in globality all the factors that you are interested in. The limit is because it is global, to know the influence of each factor inside your indicators needs more steps.

Some of them use a small number of variables and combine them with simple methods (such as Z-score) to have an additive combination of area-derived variables. Thus, others were generated using Principal Components Analysis (PCA) applied to a large data set of variables. The PCA is an adapted method to take into account the endogeneity of factors and avoid biased results. PCA provides weights to take into account these interactions between factors. It means that all your geographical units will be classified in categories according to the weight that each variable brings in the description of your territory (Lalloué et al. 2013).

These composite indexes are very useful for studies or projects related to health inequalities. They are essential for public decision-makers to guide them or for evaluating the policies.

Mostly the composite index was used to describe the level of deprivation in one area, large or small. Actually, a lot of composite indexes of deprivation are available. The difference between them is the variables that are included in. Moreover, it has been argued that deprivation comprises material and social aspects, in which material deprivation referred to the goods, services, resources, amenities, physical and living environments, while social deprivation comprised the roles, relationships, functions, customs, rights and responsibilities of membership of society and its subgroups (Townsend et al. 1987). Within this context, individuals can therefore experience multiple forms of deprivation and these may have a cumulative effect. Townsend developed an index that used four Census-derived indicators of deprivation (unemployment, household overcrowding, non-home ownership and non-car ownership). Similarly, Carstairs and Morris (Carstairs et al. 1989) developed an index for Scotland’s Postcode Sectors that comprised four variables derived from the 1981 UK Census (proportions of male unemployment, lack of car ownership, low social class, and household overcrowding). More recently, in 2009, Rey et al propose spatially defined deprivation index for analysis of health inequalities on a routine basis for all of France.

To improve the comparability and reproducibility of health inequality studies among countries, some other indexes are already European. The European Deprivation Index (EDI) is a standardised measure of social and material deprivation first developed in France (Rey et al., 2009; Merville et al., 2022), and then extended to four other European countries - Italy, Portugal, Spain and England, using available 2001 and 1999 national census data. The first indexes of Multiple Deprivation (IMD) were developed for England in 2000 by the Department of the Environment, Transport and the Regions (DETR). They used routinely collected data, incorporating direct (employment, housing, geographic access) and indirect (income, health) measures of the causes and/or consequences of deprivation, and were used by the Government to allocate billions of pounds of resources. This index was already adapted to other countries in Europe as it was done in New Zealand (Exeter et al. 2017). Composite indexes are often used in epidemiology to characterize the living environment of people and explore the potential link with health status (Brousmiche et al., 2021).

2.2 Typologies: spatial classification

This approach is interesting in several ways. It allows to produce a comprehensive description of medical desert integrating a large number of characteristics for each territory (e.g. geographic context, population). Moreover, it is a promising way to more accurately compare medical desert characteristics.

Several statistical methods exist to make spatial clustering (Neethu et al., 2013; Varghese et al., 2013): the major ones are hierarchical agglomerative clustering (HAC) alone or principal component analysis (PCA) following by HAC (Padilla et al. 2016; Chevillard and Mousquès. 2020) and k-means methods (Fayet et al., 2020). Briefly, spatial clustering needs cluster analysis as statistical method for finding homogeneous groups of territories based on the measured characteristics. It starts with each territory as a separate cluster, i.e., there are as many clusters as territories, and then combines the clusters sequentially, reducing the number of clusters at each step. The clustering method uses the dissimilarities between territories when forming the clusters (Neethu et al., 2013; Varghese et al., 2013).

Such approach reveals territories that accumulate deprivation indicators and where medical desert could be amplified by other structural difficulties (economic, remoteness, demographic, etc.). Furthermore, it provides possible explanations on the roots of medical deserts that may help to calibrate the answers (Chevillard and Mousquès. 2020). In our view, based on previous work, three dimensions are relevant to build spatial classifications that could help to qualify medical deserts and understand their roots (Chevillard and Mousquès, 2018). The first dimension is health care accessibility (defined and described in the previous section: measure of healthcare accessibility). The second dimension (that approximates care needs) describes the population characteristics and could be presented by several ecological indicators: demographic, socioeconomic, health status and household characteristics. The third one is the spatial attractiveness related to population and physicians of each territory. The global attractiveness of the environment can be resumed through the characteristics of the landscape, the share of green space, the quality of life, facilities and access to healthcare, mobility of the population, the employment opportunities and dynamism in the areas.

2.3 Reading guide

We highly recommend reading these articles:

Bertin, M., Chevrier, C., Pelé, F., Serrano-Chavez T., Cordier S., Viel F. (2014). « Can a deprivation index be used legitimately over both urban and rural areas?". International Journal of Health Geographics, 13, 22.

Brousmiche, D., Genin, M., Occelli, F., Frank, L., Deram, A., Cuny, D., Lanier, C. (2021). "How can we analyze environmental health resilience and vulnerability? A joint analysis with composite indices applied to the north of France". Science of The Total Environment 763, 142983. https://doi.org/10.1016/j.scitotenv.2020.142983

Carstairs V, Morris R. (1989). "Deprivation: explaining differences in mortality between Scotland and England and Wales". Bmj; 299(6704):886–9. PMID: 2510878.

Chevillard G., Mousquès J. (2022). "Medically underserved areas: are primary care teams efficient at attracting and retaining general practitioners". *Social Science & Medicine.*

Exeter DJ, Zhao J., Crengle S., Lee A., Browne M. (2017). "The New Zealand indexes of Multiple Deprivation (IMD): A new suite of indicators for social and health research in Aotearoa, New Zealand". PLoS One. 3;12(8):e0181260. doi: 10.1371/journal.pone.0181260. PMID: 28771596; PMCID: PMC5542612.

Guillaume E., Pornet C., Dejardin O., Launay L., Lillini R., Vercelli M., Dell'Olmo M., Fernandez Fontelo A., Borrell C., Ribeiro AI., De Pina MF., Mayer A., DelpierreC., Rachet B., Launoy G. (2016). "Development of a cross-cultural deprivation index in five European countries". Journal of Epidemiology and Community Health. 70(5):493-9. doi: 10.1136/jech-2015-205729. Epub 2015 Dec 11.

Lalloué B., Monnez JM., Padilla C., Kihal W., Le Meur N., Zmirou-Navier D., Deguen S. (2013). "A statistical procedure to create a neighborhood socioeconomic index for health inequalities analysis". Int J Equity Health. 12:21. doi: 10.1186/1475-9276-12-21.

Merville, O., Launay, L., Dejardin, O., Rollet, Q., Bryère, J., Guillaume, É., Launoy, G., (2022). "Can an Ecological Index of Deprivation Be Used at the Country Level? The Case of the French Version of the European Deprivation Index (F-EDI)". International Journal of Environmental Research and Public Health 19, 2311. https://doi.org/10.3390/ijerph19042311

Neethu, C.V., Subu, S., (2013). "Review of Spatial Clustering Methods". International Journal of Information Technology Infrastructure 2.

Padilla C., Kihal-Talantikit W., Perez S. Deguen S. (2016), "Use of geographic indicators of healthcare, environment and socioeconomic factors to characterize environmental health disparities". Environmental Health. 15: 79.

Rey G., Jougla E., Fouillet A., Hemon D. (2009), "Ecological association between a deprivation index and mortality in France over the period 1997–2001: variations with spatial scale, degree of urbanicity, age, gender and cause of death". BMC Public Health; 9:33.

Townsend P. (1987). "Deprivation". Journal of social policy. 16(2):125–46.

Varghese, B., Unnikrishnan, A., PouloseJacob, K., (2013). Spatial Clustering Algorithms – An overview.

Extensive readings:

Anthopolos R., James SA., Gelfand AE., Miranda ML. (2011). “A spatial measure of neighborhood level racial isolation applied to low birthweight, preterm birth, and birthweight in North Carolina”. Spatiotemporal Epidemiology, 2:235–246.

Bell N., Schuurman N., Hayes MV. (2007). “Using GIS-based methods of multicriteria analysis to construct socio-economic deprivation indexes”. International Journal of Health Geographics, 6:17.

Carstairs V. (1995). “Deprivation indexes: their interpretation and use in relation to health”. Journal of Epidemiology and Community Health, 49 (Suppl 2):S3–S8.

English_Index_of_Multiple_Deprivation_2015_- Guidance.pdf available at https://www.gov.uk/government/statistics/english-indexes-of-deprivation-2015

3 Annexes

Annex 1: Survey

The way to qualify medical deserts in each country will depend on the indicators and tools available. One important thing is that the level of complexity of the accessibility indicator (Part I) constructed by each country, and consequently the number of dimensions it covers, will influence the choice of the methods used to characterize your territory (Part II) (in terms of the balance of dimensions or redundancy between indicators). Thus, the choice of the method to create spatial typology will come in a second place after the accessibility indicator constructed in the first place.

- **Survey part I: building spatial accessibility index**

The deployment of potential spatial access measures requires the specification of a set of six parameters, namely: (1) a spatial unit of reference for the population, i.e. a definition of residential areas (e.g. census tracts); (2) an aggregation method, i.e. to determine the point of each residential areas where population and supply will be counted; (3) a supply/demand measure; (4) a supply/demand interactions modelling method and (5) a type of distance to be used in computing the accessibility measures selected [Apparicio 2017] and (6) an accessibility measure.

Lexicon:
Spatial unit of reference: the operational area for the definition of the index of spatial accessibility
Aggregation method: to determine the point of each residential area where population and supply will be counted
Supply/demand measure: How to measure supply and demand? By the number of inpatient beds, equipment or professionals (number, weighted number by activity level or active file…
Supply/demand interactions modelling method: for example, how to model patients' travel behavior when they are searching for healthcare? Theoretical statistics distribution or healthcare utilization database?
Distance type: Euclidean distance (straight-line), Manhattan distance (distance along two sides of a right-angled triangle opposed to the hypotenuse), and shortest network time distances according to the mode of transportation used (on foot, by car, by bicycle or by public transit).

The survey below focuses on parameters and tools. Please select the relevant elements and add as many lines as necessary:

	Options	**Data**	**Spatial unit**	**Availability (please check)**
1. Spatial unit of reference		Maps shapefiles (.shp)	Region	☐
			Department	☐
			Postal codes	☐
			Census tracts	☐
			Census blocks	☐
			Others (please indicate):	

2. Aggregation methods				
Health services (HS)/ Health professionals (HP)	At their professional addresses	Geocoded professional addresses (latitude, longitude) *Please repeat this line for each service considered **		☐
	At spatial unit's centroid	Number of HP of each *Please repeat these lines for each service considered **	region	☐
			department	☐
			postal codes	☐
			census tracts	☐
			census blocks	☐
			others (please indicate):	
Population	At spatial unit's centroid	Number of inhabitants of each	region	☐
			department	☐
			postal codes	☐
			census tracts	☐
			census blocks	☐
			others (please indicate):	
3. Supply/Demand measure				
Supply	HP Number	Number of HP by type of each HP (ambulatory and hospital HP) *Please repeat these lines for each service considered **	Region	☐
			Department	☐
			Postal codes	☐
			Census tracts	☐
			Census blocks	☐
			Others (please indicate):	☐
	HP full time equivalent (FTE)	Full time equivalent (FTE) *Please repeat these lines for each service considered **	Region	☐
			Department	☐
			Postal codes	☐
			Census tracts	☐
			Census blocks	☐
			Others (please indicate):	
	Active patient list	Active patient list	Region	☐

		Please repeat these lines for each service considered *	Department	☐
			Postal codes	☐
			Census tracts	☐
			Census blocks	☐
			Others (please indicate):	
	HS material resources	Number of medical equipment (e.g.: beds of hospital medical unit of each health service considered, MRI scanners…) *Please repeat these lines for each service considered* *	Region	☐
			Department	☐
			Postal codes	☐
			Census tracts	☐
			Census blocks	☐
			Others (please indicate):	☐
Demand		Population volume by	region	☐
			department	☐
			postal codes	☐
			census tracts	☐
			census blocks	☐
			others (please indicate):	☐
		Population distribution by age for each	region	☐
			department	☐
			postal codes	☐
			census tracts	☐
			census blocks	☐
			others (please indicate):	☐
		Population distribution by age and social class for each	region	☐
			department	☐
			postal codes	☐
			census tracts	☐
			census blocks	☐
			others (please indicate):	☐
4. Supply/Demand Interaction	Real world behavior	Healthcare utilization database by age or age and social class (please	Region	☐
			Department	☐
			Postal codes	☐

		fill in for each service considered)* *Please repeat these lines for each service considered **	Census tracts	☐
			Census blocks	☐
			Others (please indicate):	☐
5. Distance	*If there is a distance matrix available…*	Distance matrix scale	Region A to region B	☐
			Depart A to depart B	☐
			Postal codes A to B	☐
			Census tracts A to B	☐
			Census blocks A to B	☐
			Others (please indicate):	☐
		Distance matrix type	Euclidean	☐
			By car	☐
			On foot	☐
			By bicycle	☐
	If there is not a distance matrix available, we have to build the distance matrix ourselves …	Road network GIS file (junction, stretches of road…)		☐
		General transit feed specification (GTFS) files		☐
		Bicycle paths data		☐
6. Tools	Distance computing Geolocation Geoprocessing	GIS Tool		☐
	Data processing Indicator computing	Python/SAS/R		☐

** Please add as many lines as necessary for each type of services including in the field of medical desert in your country (for example: GPs, emergency service, pharmacy).*

Some additional questions for you to complete the picture:

- Can you specify how social classes are defined?

- Do you have household motorization rates that allow you to define the types of transport commonly used (cf. xSFCA method on transport modes)?

- Finally, given the data defined in the table, what sort of accessibility measure (density, distance, XSCFA indicators) do you expect to define for the types of care considered?

Comments and questions for us:

- **Survey part II: building spatial taxonomy**

The French team proposes appropriate tools and methods to describe medical deserts according to the specificities of each country. Three approaches are possible, one single variable, a composite index as a global view and a categorization of your geographical units. The first table asks you questions about indexes that already exist and are validated in your country. The second table will give us information on the domains and dimensions which influence medical desert in your country, the data available and at which geographical unit.

Table 1: Useful information related to indexes

Types of analysis	**An index** **Do you have some composite index that already exists and has been validated in previous studies in the following domains?**	**Data** **What data are used to create this indicator?**	**Literature review** **Could you give us an article or a website that explains the methods used for this index?**	**Availability** **What is the smallest geographic unit with this information available?** Region Department Municipalities Census tracts / blocks?
Index of combined dimensions				
Deprivation	Yes ☐ No ☐ Name?			
	Example in France Yes FDEP (index of deprivation: score)	% of unemployment in the active population, % of workers, % of high school and median income	Rey G, Jougla E, Fouillet A, Hemon D. Ecological association between a deprivation index and mortality in France over the period 1997–2001: variations with spatial scale, degree of urbanicity, age, gender and cause of death. BMCPublic Health. 2009;9:33.	Index available at the municipality level but data available until census blocks

Health status	Yes ☐ No ☐ Name?			
Landscape	Yes ☐ No ☐ Name?			
Mobility	Yes ☐ No ☐ Name?			
Multiple domains	Yes ☐ No ☐ Name? Please which domains?			
OTHERS	Name?			

Table 2: Useful information related to appropriate variables for your country, and the creation of a categorization of the geographical units

Dimensions	Selections Among the following dimensions, select those which have to be taken into account to describe the domain characteristics in your country	Data What data are used in the following dimensions? The proposed data are not exclusives	Availability Do you have this information easily available? Where? (website, institute, article …). Information that can help us understand it	Geographical unit What is the smallest geographic unit with this information available? Region (NUTS 2) Department (NUTS 3) Municipalities Census tracts / blocks?	Temporal From which year, do you have the data? By time lag?
FIRST DOMAINS: HEALTHCARE ACCESSIBILITY **According to the complexity of the APL used to described your healthcare accessibility, data from others domains will be adjusted.**					
Healthcare accessibility	☐	Share of GPs over 55 or 60 years old.	Yes ☐ No ☐ Where?		

		Other data more appropriate for your country: Please add data		Which geographic unit?	
SECOND DOMAINS: POPULATION					
Demographic	☐	Share of the population by age group?	Yes ☐ No ☐ Where?		
		Other data more appropriate for your country: Please add data		Which geographic unit?	
Socio-economic	☐	Share of working age population Share of elderly people living alone Share of single parent family Share of education Share of Unemployment Household income Share of the non-owners of residential houses	Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Where?		
		Other data more appropriate for your country: Please add data		Which geographic unit?	
Health status	☐	Comparative mortality index Premature mortality (per 100 000 inhabitants) Avoidable mortality (per	Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐		

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		100 000 inhabitants) Infant mortality (100 life births)	Yes ☐ No ☐		
		Other data more appropriate for your country: Please add data		Which geographic unit?	
OTHERS (Example: out of pocket….)	Add name of the dimension	Which data?		Which geographic unit?	
DOMAIN: SPATIAL ATTRACTIVENESS					
Landscape	☐	Density of the population Share of green space Degree of urbanization	Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐		
		Other data more appropriate for your country: Please add data		Which geographic unit?	
Facilities	☐	Distance to the closest big city (minutes) Distance to the closest proximity services poles (minutes)	Yes ☐ No ☐ Yes ☐ No ☐		
		Other data more appropriate for your country: Please add data		Which geographic unit?	
Attractivity	☐	Distance to coastline (minutes) Share of vacant accommodation (%) Share of second homes (%)	Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐		

		Average annual net migration (%)			
		Other data more appropriate for your country: Please add data		Which geographic unit?	
Mobility	☐	Personal mobility: daily mobility using a car (%), public transport (%), by walking (%) Professional mobility: commuting to and from the place of work, same municipality (%), same department (%)	Yes ☐ No ☐ Yes ☐ No ☐		
		Other data more appropriate for your country: Please add data		Which geographic unit?	
OTHERS (example: out of pocket….)	Add name of the dimension	Which data?		Which geographic unit?	

Comments and questions for us:

Annex 2: Tables for each calculation steps of the indicators

- *Data importation*

Table 1: Data_tmps

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total
1	59001	59001	0	0	469
2	59001	59002	26	2	469
3	59001	59004	50	0	469
4	59001	59005	59.5	2	469
5	59001	59006	37	0	469

- *Distributed density*

Table 2: Data_final_pop_des

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	POP_DES
1	59001	59001	0	0	469	1	469
2	59001	59002	26	2	469	0	4376
3	59001	59004	50	0	469	0	1275
4	59001	59005	59.5	2	469	0	3458
5	59001	59006	37	0	469	0	217

Table 3: Data_tmps

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	POP_DES	Mij
1	59001	59001	0	0	469	1	469	1
2	59001	59023	8	0	469	1	541	1
3	59001	59026	10	1	469	1	1172	1
4	59001	59048	2	0	469	1	520	1
5	59001	59085	2.5	0	469	1	305	1

Table 4 : DML

	COM_ORIGIN	sj_sum	pi_sum	DD
1	59001	5	11613	43.055196762
2	59002	7	9070	77.177508269
3	59003	7	8488	82.46936852
4	59004	15	11094	135.20822066
5	59005	21	19435	108.05248263

- *2SFCA indicator*

Table 5 : Sum_population

	COM_DESTIN	Sum_pop
1	59001	68032.484
2	59002	75800.422
3	59003	26521.712
4	59004	30268.295
5	59005	43827.782

Table 6: Cd_supply

	COM_DESTIN	Sj
1	59001	0
2	59002	2
3	59003	0
4	59004	0
5	59005	2

Table 7: Table ratio

	COM_DESTIN	Sj	Sum_pop	ratio_cd
1	59001	0	68032.484	0
2	59002	2	75800.422	0.0000263851
3	59003	0	26521.712	0
4	59004	0	30268.295	0
5	59005	2	43827.782	0.0000456332

Table 8: Matrice ratio

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	ratio_cd	Sum_pop
1	59001	59001	0	0	469	1	0	68032.484
2	59001	59002	26	2	469	0	0.0000263851	75800.422
3	59001	59004	50	0	469	0	0	30268.295
4	59001	59005	59.5	2	469	0	0.0000456332	43827.782
5	59001	59006	37	0	469	0	0	56149.618

Table 9: 2SFCA

	COM_ORIGIN	two_SFCA
1	59001	84.958446378
2	59002	39.061985137
3	59003	50.714644668
4	59004	117.52070221
5	59005	107.19284005

- *3SFCA indicator*

Table 10: Sum_supply

	COM_ORIGIN	Sum_supply
1	59001	43.646
2	59002	24.994
3	59003	18.003
4	59004	34.002
5	59005	44.996

Table 11: data_final_Sum_supply

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	Sum_supply
1	59001	59001	0	0	469	1	43.646
2	59001	59002	26	2	469	0	43.646
3	59001	59004	50	0	469	0	43.646
4	59001	59005	59.5	2	469	0	43.646
5	59001	59006	37	0	469	0	43.646

Table 12: data_final_Gij

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	Sum_supply	Gij
1	59001	59001	0	0	469	1	43.646	0
2	59001	59002	26	2	469	0	43.646	0
3	59001	59004	50	0	469	0	43.646	0
4	59001	59005	59.5	2	469	0	43.646	0
5	59001	59006	37	0	469	0	43.646	0

Table 13: Sum_pop

	COM_DESTIN	Sum_Population
1	59001	0
2	59002	2211.5888846
3	59003	0
4	59004	0
5	59005	1480.5373928

Table 14: data_final_Sum_Pop

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	Sum_supply	Gij	Sum_Population
1	59001	59001	0	0	469	1	43.646	0	0
2	59001	59002	26	2	469	0	43.646	0	2211.5888846
3	59001	59004	50	0	469	0	43.646	0	0
4	59001	59005	59.5	2	469	0	43.646	0	1480.5373928
5	59001	59006	37	0	469	0	43.646	0	0

Table 15: data_final_ratio

	COM_ORIGIN	COM_DESTIN	Time	Sj	pop_total	wij	Sum_supply	Gij	Sum_Population	Rj
1	59001	59001	0	0	469	1	43.646	0	0	0
2	59001	59002	26	2	469	0	43.646	0	2211.5888846	0.0009043272
3	59001	59004	50	0	469	0	43.646	0	0	0
4	59001	59005	59.5	2	469	0	43.646	0	1480.5373928	0.0013508608
5	59001	59006	37	0	469	0	43.646	0	0	0

Table 16: THREE_SFCA

	COM_ORIGIN	i3SFCA
1	59001	49.582768606
2	59002	64.188454624
3	59003	86.15244112
4	59004	161.75397343
5	59005	105.24306388

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Co-funded by the Health Programme of the European Union