Role of geography in the reorganization of the Italian National Health Service: Implementation of geographic information in the logistics and resilience of organizational structures

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Abstract

The study, carried out at the Local Healthcare Authority in Reggio Emilia, Italy, focused on required travel of its employees with reference to length of travel route, degree of coverage through local public transport, degree of overlapping travel (useful to assess the feasibility of car sharing initiatives) and plans for shift work. The goal was to identify main obstacles when attempting to improve the reliability and scalability of this type of analysis, so that it can be used for regular updates. It was found that, on the one hand, it is necessary to promptly identify changes in the staff structure due to turnover that particularly affects health practitioners, such as doctors and fixed-term employees, while, on the other it is mandatory to comply with the provisions of Italian Law according to which, mobility managers must draw up annual commuting plans with an analysis of the routes travelled. The results of this work are likely to have useful implications for the improvement of the logistics system and, in particular, for the resilience of healthcare organizations.

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Introduction

Since 2016, the Local Healthcare Authority (*Azienda Unità Sanitaria Locale* - AUSL) in Reggio Emilia, Italy has been carrying out a study of the commuting routes of its employees based on geolocation in order to develop useful measures aimed at rationalizing not only their systematic mobility, but also the use of the parking lots at the sanitary facilities involved. All AUSLs are required to draft a commuting plan under the Italian Ministerial Decree No. 27/3/98 and the more recent Italian Law No. 77/2020. In addition, all travels during working hours are subject to the Italian Legislative Decree No 81/2008 as regard safety aspects. However, there is a lack of regulatory measures concerning accessibility and mobility, even though the current structures are among the major traffic attractors of urbanized areas and must draft Sustainable Urban Mobility Plans. To update annually the commuting plan as required by law, it is necessary to identify procedures that can easily and economically be replicated using the administrative and functional information generated by the execution of current activities. The Reggio Emilia AUSL was initially divided in two separate entities, the Santa Maria Nuova Hospital (SMN) and the Reggio Emilia AUSL, which subsequently were merged into a single body, the Reggio Emilia AUSL. This body currently counts over 7600 employees (increased to 8000+ during the COVID-19 pandemic), more than 6 hospitals, located in as many districts and 11 local healthcare assistance hubs named '*Case della Salute*', and it also offers further local assistance and administrative management services.

Materials and methods

Data collection

The data about the AUSL employees were chosen among the information stored in the management systems of the Legal Personnel Management Service (SGGP), and they refer to the beginning of the contract or the main administrative stages in the employee's career. The information includes registration number, tax code (CF), domicile/residence address, department/structure of operation and whether shift work. It should be noted that the management systems contain other information that may be useful for further processing.

As regard the geolocation of addresses, reference is made to the street numbers registry developed by the Emilia-Romagna Region for the entire regional territory. This is a freely accessible database where each housing unit is identified with two types of coordinates: the ones of the housing unit itself, and those of its projection on the road network. For this work, for a very limited number of cases, reference was also made to the geolocation services provided by Google Maps and OpenStreet Map APIs. OpenRoute Service APIs were used for the accessibility analysis of AUSL facilities from individual housing unit.

Software

Only open-source software applications were used, in particular, QGIS (https://qgis.org/en/site/) and its plugins MMQGIS (https://plugins.qgis.org/plugins/mmqgis/) and ORS tools (https://plugins.qgis.org/plugins/ORStools/) were used for the geographic representation and analysis, and PostGIS (https://postgis.net/) was used as a geographic database, as a repository of collected and processed data, and for all further processing. e-GeCo (e-GeoCoding) software from Google (https://developers.google.com/maps/documentation/javascript/geocoding), a client application that can be used for both the normalization of the addresses' toponymy and their association with the corresponding coordinates, was provided by the Emilia-Romagna Region and used to access the regional database of addresses. The software also offers an assisted normalization function for cases that cannot be solved automatically, and its batch mode functionality allows processing of large amounts of data.

Data processing

The initial data were extracted from the management system of the SGGP and underwent a first process of normalization and georeferencing in batch mode using e-GeCo. As this application also provides each element with two indices that describe the degree of reliability of the toponym/street number combination and the corresponding values in the regional database of roads and addresses, it was possible to easily select the records for which the automatic match was not feasible or had margins of uncertainty. A manual assisted normalization was performed on this subset of data, using the specific functionality of the same software. After this operation, the matching proved to be impossible for a small number of Emilia-Romagna residents and, in addition, a given number of people who lived in the region although they were formally domiciled in other areas. In all these cases, georeferencing was carried out using Google Maps and OpenStreet Map APIs with the batch mode of QGIS plugin MMQGIS. Finally, once the localization of the domiciles of all employees was available, we ran the batch mode of QGIS once again through its ORS tools plugin (which uses the OpenRoute Service APIs), to analyse their accessibility conditions to the AUSL facilities and their potential routes.

Figure 1. Distribution of the domiciles of active employees at AUSL_RE on the basis of the administrative information available.

Results

It was possible to normalize and georeference 90% of the employees' households through the regional database of addresses and street numbers. As for the remaining 10%, the domiciles were located outside of the region and, therefore, georeferencing was only possible through Google and OpenStreet Map APIs. While a small number of them actually were found to reside just beyond the regional border with Lombardy (but mainly active in the neighbouring northern area of the Reggio Emilia AUSL), the majority are people who, despite informally living on the regional territory, had not changed their formal residence or domicile, as they mainly

were on fixed-term contracts or hired for just a few months as shown in Figures 1 and 2.

Considering the poor matching to the actual situation of extra-regional domiciles (except for those domiciled in the provinces of Mantua and Cremona) and their numerical marginality as well, it was decided to exclude them from subsequent processing, until formal information about their actual residence would be available.

The next steps were the following: dividing the individual employees by work location (Figure 3), using the obtained georeferences to highlight their possible routes in their commuting, estimating their respective lengths of travel and creating a first segmentation with the obtained data (Table 1 and Figures 4 and 5). Furthermore, with regard to the employees working at the SMN

Table 1. Employees of Santa Maria Nuova and the Local Healthcare Authority (AUSL) in relation to the distance from home to work.

	Employees AUSL			Employees Santa Maria Nuova	
Distance (m)	n. Employees	% Employees	Distance (m)	n. Employees	% Employees
0-400	114	3.0%	0-400	33	1.1%
400-1600	652	16.9%	400-1600	580	19.8%
1600-4000	518	13.4%	1600-4000	661	22.6%
4000-10,000	1087	28.2%	4000-10,000	612	20.9%
10,000-20,000	942	24.5%	10,000-20,000	527	18.0%
20,000-40,000	371	9.6%	20,000-40,000	285	9.7%
40,000-80,000	94	2.4%	40,000-80,000	61	2.1%

Figure 2. Distribution of the domiciles of employees working at Santa Maria Nuova Hospital on the basis of available administrative information.

hospital, locations were verified with respect to areas accessible by bike in 5/10/15 minutes in consideration of their greater urban share. Overall, as many as 43% of the employees were found to be domiciled within the areas accessible by bike within 10 minutes (Figure 6).

At a later time, a detailed analysis was carried out with respect to two particular cases that arose upon the merging of the SGGP and a training centre (the '*Luoghi di prevenzione*') situated in a new headquarter, which occurred after the fusion of the Reggio Emilia AUSL and SMN and the opening of a new local healthcare
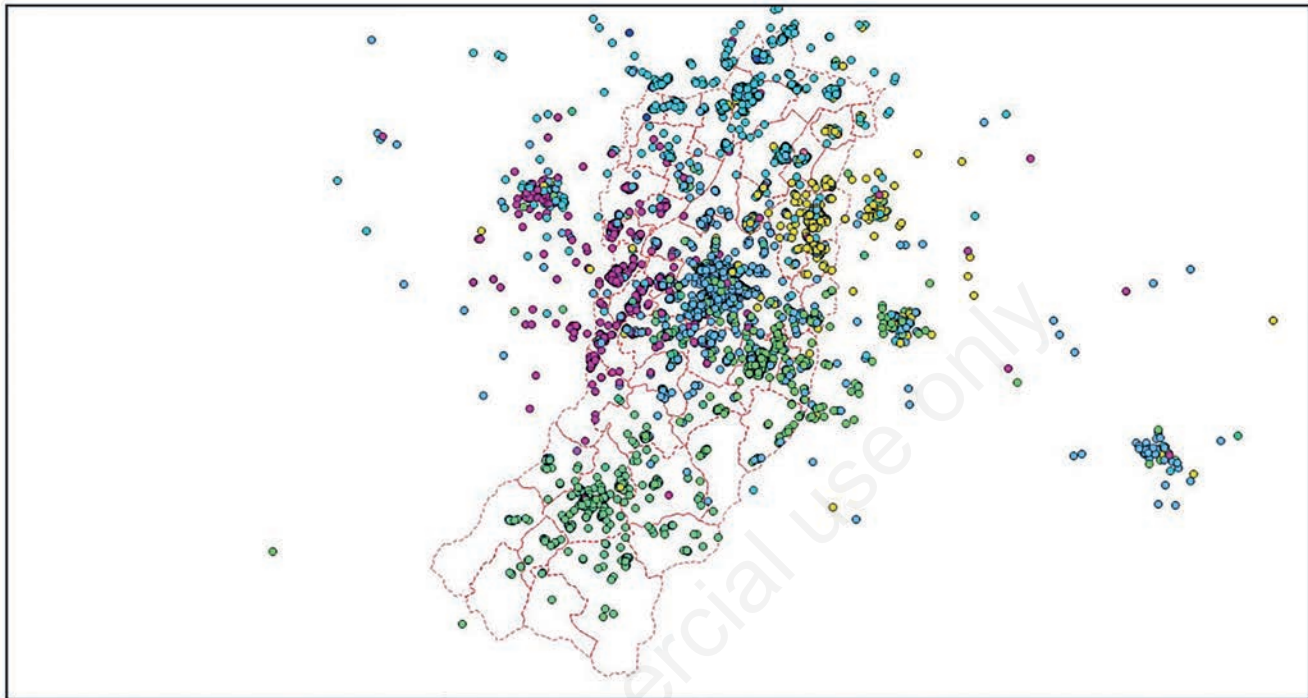

Figure 3. Distribution of the domiciles of AUSL employees by place of work.
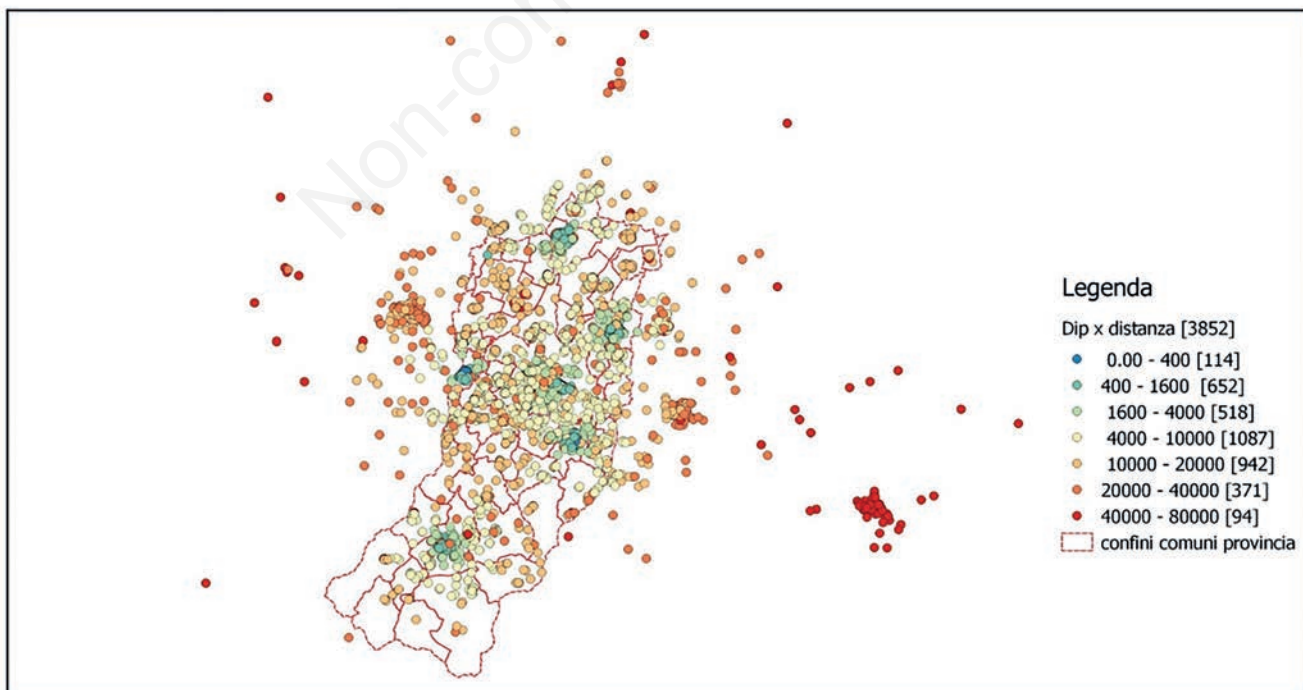

Figure 4. Division of the domiciles of AUSL employees by distance from the workplace in meters.

assistance hub. In both cases, while the initial objective was to estimate the potentially higher demand for public transport on some existing urban lines possibly leading to route modifications or new dedicated stops, an analysis was also conducted on the degree of overlapping routes of individual employees. The aim was to evaluate the modal profile of workers in the new offices in terms of potential use of bicycles and carpooling and, in a future perspective, corporate car sharing, because all staff involved has the same workplace and working hours. The analysis allowed us to identify even small clusters for which it might be possible to study tailored solutions (Figure 7).

Concluding remarks

Our work considered the existing regulatory framework in an attempt to build a knowledge-based on commuting that:

i) relies on a procedure capable of exploiting the already existent administrative data and that was fast and cheap enough to be periodically replicable with standardized methods (also considering the regulatory provision that requires the annual drafting of a specific employee commuting plan to reduce the use of private means of transport - clause 4, art. 229, Italian Legislative Decree No 34/2020 -), as well as easily combined with other information relating to mobility management (which can be collected, for example, from parking management systems, public transport fare concessions, financial incentives for the use of bicycles promoted by the companies themselves or the local authorities, *etc.*); and

ii) allows the segmentation of people into groups characterized by sufficiently homogeneous mobility needs. The mainly useful criteria are geography and work shifts, as they define the nature of travel and the plans to promote intermodal solutions, soft mobility and car-pooling/car-sharing initiatives.

The need to segment people according to their commuting experience to develop targeted actions arises from the observation of the limits shown by the previously adopted approach by the Emilia-Romagna AUSLs towards this issue, which was based on the submission of questionnaire-based surveys to all employees. The aforementioned limits can be summarized as follows:

i) The number of employees and the heterogeneity of their duties create numerous different profiles in terms of mobility needs, also because variable degrees of flexibility are needed (*e.g.*, in hospital shifts). In this framework, it is extremely difficult to conceive questions that are broad enough to address such differentiated needs and, at the same time, sufficiently clear and concise to suit the questionnaire templates:

ii) Participation of employees is low, probably due to the issues highlighted in the previous point, and the collected data are not always easily interpretable. Furthermore, as also experienced in other AUSLs in the region, the reiteration of questionnaire-based surveys finds a progressively decreasing response level, which makes this tool even less suitable to periodic submission (30% of SMN employees and 28% of the AUSL ones answered the questionnaire-based survey in 2010, percentages that in 2015 dropped to 9% and 17%, respectively. Indeed it represents a very expensive and time-consuming method, both with respect to preparation as well as collection and processing, that tells us that approach is found wanting and therefore incompat-
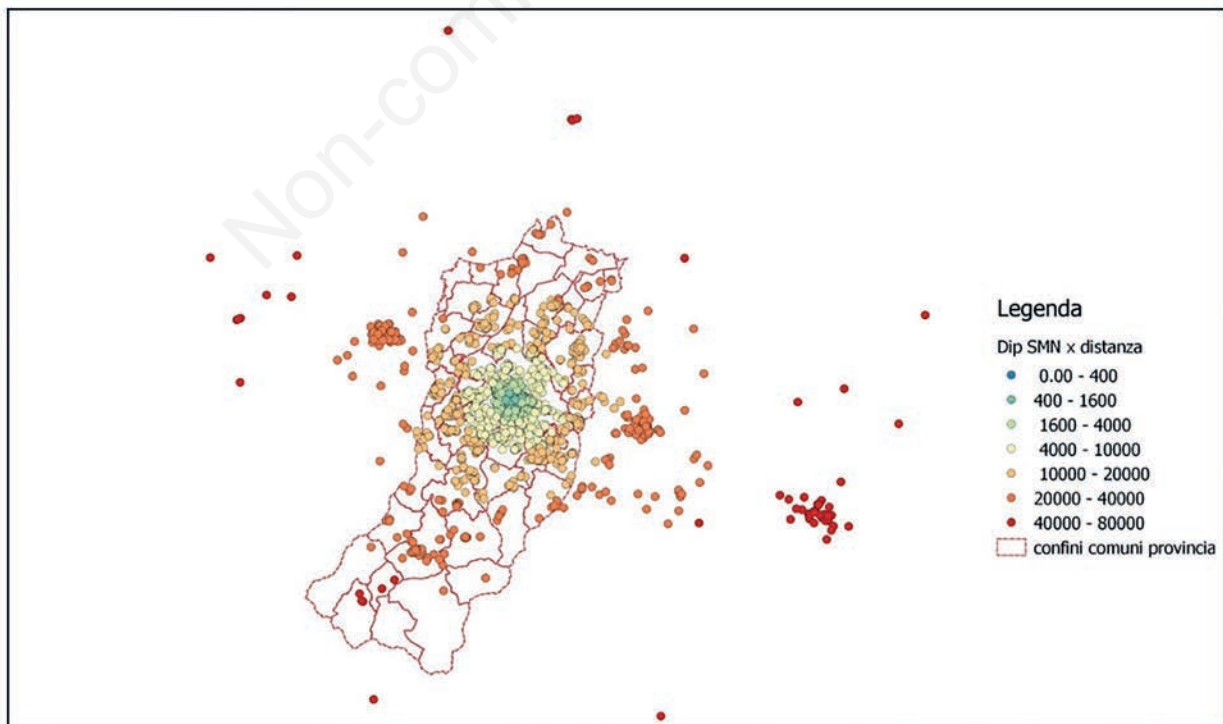

Figure 5. Division of the domiciles of Santa Maria Nuova employees by distance from the workplace in meters.
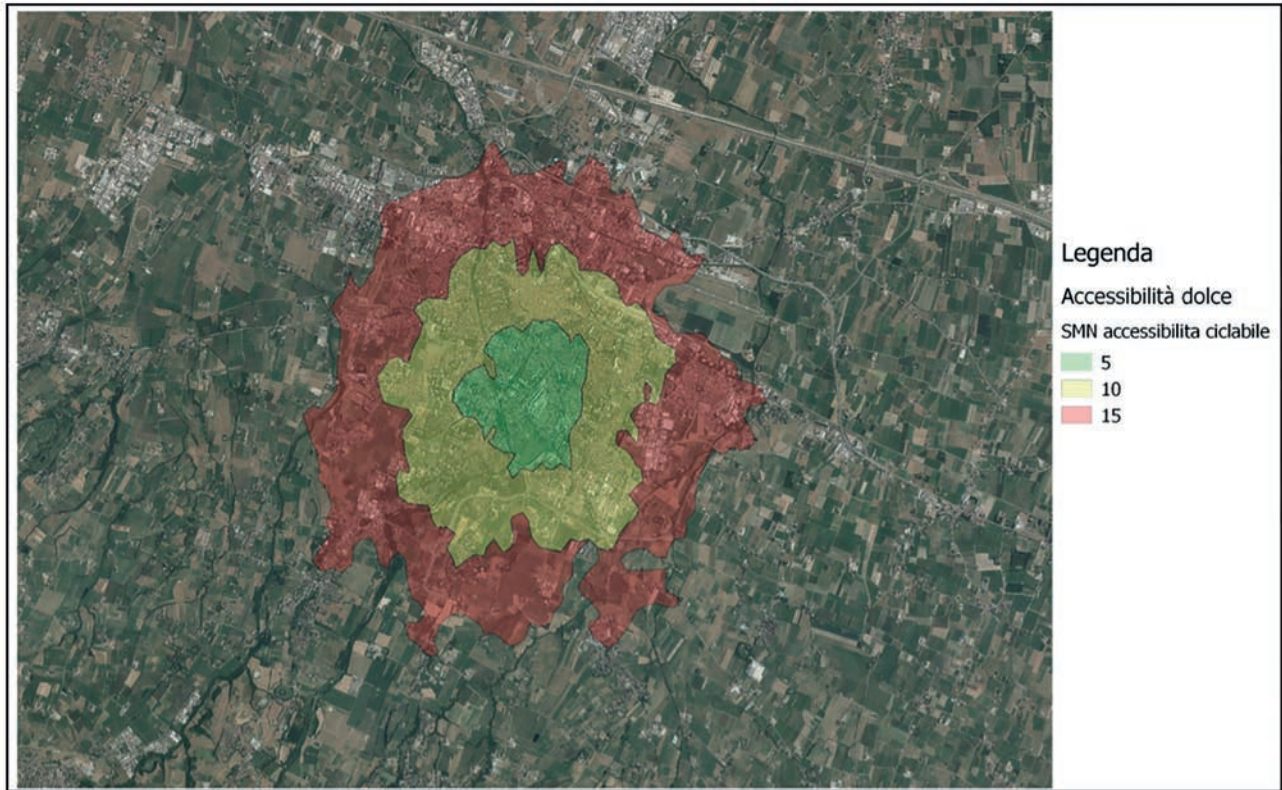
Figure 6. Cycle accessibility to Santa Maria Nuova in 5-10-15 minutes. 20.9% of the operators of this garrison are within the accessibility area within 5 minutes, another 22.6% within 10 minutes.
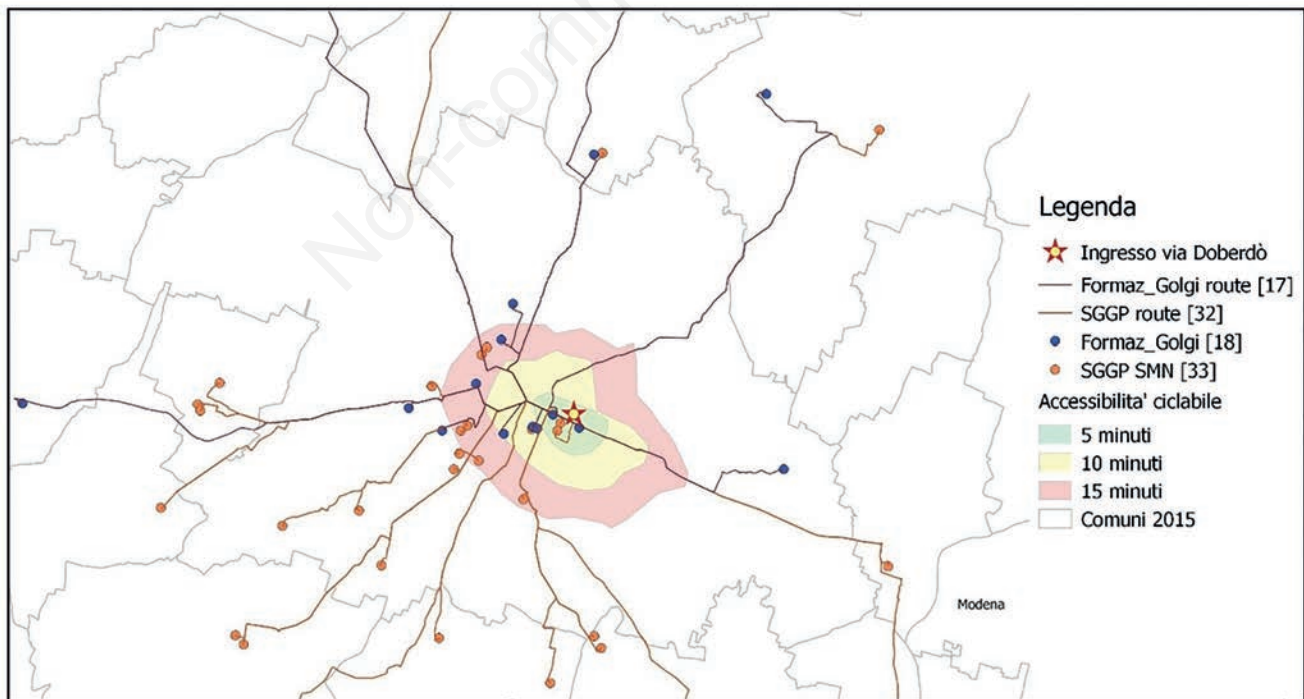

Figure 7. Case of two services, the Legal Personnel Management Service and the Training Centre since 2018 concentrated in a single location. Verification of: 1_ locations of the domiciles with respect to the cycle accessibility areas and for main urban public transport lines; 2_ the routes used by workers to identify clusters to design carpooling or car sharing measures.

ible with a periodic review of the mobility management strategies required by the Italian legislation. If, on the one hand, the data collected with the questionnaires highlight a generic appreciation of the smart mobility eco-friendliness by the employees, on the other they underline their static attitude towards commuting travel modes, which in fact discourage the identification and implementation of effective mobility management initiatives. In fact, the commuting needs are so varied and fluid that they discourage users to think about different possibilities from the pragmatic 'do it yourself';

iii) Thanks to the segmentation of the mobility needs we experienced, it is possible to further isolate subsets of employees characterized by particular and more defined needs, and to identify possible specific solutions; and

iv) The segmentation can be further implemented with other administrative data of human resource offices such as, for example, parental and/or assistance leave, *etc*. In fact, the composition and features of these groups must be dynamically interpreted in order to define efficient and economically viable solutions and to evaluate the real effectiveness of smart mobility services.

The experience generally showed its substantial practicability in the regional context of Emilia-Romagna, but it also made it possible to highlight two critical issues that need to be solved:

i) The registered employee addresses are not normalized. From further processing carried out during the first wave of the pandemic, it was possible to verify that even the registries of public healthcare beneficiaries (and therefore the relevant municipal registries as well) contain information relating to non-standardized domiciles/residences. The e-GeCo application, which enables to perform normalization both automatically and in assisted manual mode, has made it possible to circumvent this shortcoming for all people domiciled/resident in the region, with very few exceptions. However, it is evident that the manually-assisted normalization, which is the only time-consuming phase of the entire process, could be avoided if the municipal registries were already normalized and the applications used by the regional Public Administration were equipped with auto-populating fields or drop-down menus, rather than free text fields (to be reserved for use in exceptional cases only). It is evident that the benefits of this type of solutions are universal, and not limited to the present case;

ii) The addresses relating to domicile/residence of AUSL employees contained in the management system registers are acquired at the time of hiring and only updated in case of administrative needs. This means that the information is not always up to date or that the formal situation does not correspond to the reality (as demonstrated in our study by the employees who were found to be domiciled and resident in different regions). A possible solution to this inconvenience can be the execution of a periodic alignment of the personal data in the management system with the ones in the registry of public healthcare beneficiaries (as each employee, who is domiciled or resident in the region is in that archive too); however, the main solution seems to be to include in the contracts a clause instructing the employees to update the information about their habitual residence (this information has further practical implications for the employees that must guarantee their availability). For this purpose, the Emilia-Romagna Region allows the possibility to directly update this information from the Human Resources

Management portal (GRU), a web-based help desk for public healthcare workers which has been implemented after our first experimentation.

In addition to its above-described use, the work carried out for the household geolocation of the SSN employees may also be of first-rate relevance to increase the resilience of the SSN to adverse environmental events or major disasters. In fact, the availability of this information may be useful in two main circumstances, in particular:

i) in case of recurrent adverse environmental events (such as temporary interruptions of road traffic caused by hydrogeological instability, flooding or bridge closures due to flooding), it allows to rapidly identify the healthcare workers involved and temporarily isolated, making it possible to temporarily replace them by reorganizing the shift system used and therefore limiting the negative effects on the whole system; and

ii) in case of major environmental disasters (*e.g.* earthquakes) in which territorial isolation is expected to be more radical and extended, it allows the awareness of employees residing in concerned areas that should facilitate their potential involvement in first-aid operations, as they may already be onsite.

The COVID-19 pandemic has stressed the importance of the digitalization of processes to ensure greater effectiveness and resilience of healthcare systems. Thanks to the combination of digitalization and organizational innovations it will be possible not only to identify an effective connection between hospital workers and local employees, but also to transfer part of assistance activities to the patients' homes. Likewise, it is only through an advanced digitalization that it will be possible to design and enhance the development of a logistics system that fosters a more local-centred and domestic healthcare, on a 'hub & spoke' model. If this issue is not addressed, it can translate into a factor limiting healthcare access for the most vulnerable (an evidence of this can already be seen in the differences between the amount of specialist visits in the '*Aree Interne*' and the overall national figure - 2415 against 4130 per thousand residents as noted by the Italian '*Agenzia Coesione Territoriale*'). [A similar procedure could be applied to groups of users whose evacuation requires special measures due to their health conditions. The '*Aree Interne*' represents Italian territorial realities characterized by significant problems of accessibility to the centres of supply of essential services such as health and education. They have been identified on the basis of indicators chosen by the Territorial Cohesion Agency to implement the 2014-2020 Partnership Agreement for Italy aimed at addressing the demographic challenges of the regions or responding to the specific needs of geographical areas characterized by serious and permanent disadvantages natural and demographic, as stated by art. *Treaty on the Functioning of the European Union*, point 174.].

In this perspective, the use of geo-localized street numbers of the domiciles not only of employees but also of the SSN patients as well, represents a necessary information to develop logistic solutions for local healthcare services. Moreover, the experience gained during the pandemic has highlighted the need to review the organization of the flow of information and disease reporting; within these data, it is necessary to get a fast geographic contextualization of events reported, as well as to quickly identify the occurrence of space-time clusters. The latter operation has proved to be impossible, as it is exclusively based on aggregated data on the basis of administrative boundaries that poorly represent the geography of really functional areas.