Access to emergency care services and inequalities in living standards: some evidence from two Italian northern regions

Andrea Marino, Marco Pesce, Raffaella Succi

1. Introduction

The goal of this short paper is twofold. First, we want to provide an estimate of accessibility to emergency care services at a very geographically disaggregated level, namely census enumeration areas (CEAs). Secondly, we want to evaluate whether and how differences in accessibility to emergency care services relate to health inequalities and regional differences in living standards.

Quick and timely access to emergency medical services is a key factor in reducing the health implications -in terms of both mortality and disability- of adverse events. Thus, in a well-designed health system the geographical distribution of emergency care services should be able to minimize the share of people whose access time lies beyond critical thresholds. In recent years, a growing number of studies concerning different countries and/or regions have been devoted to quantify access times to emergency care services. A far from exhaustive list of recent papers includes Tolpadi et al. (2022) for the USA. Tang et al. (2021) for the Sichuan province of China. Lilley et al. (2019) for New Zealand. Kisiala et al. for Poland (2021). Silva and Padeiro for the metropolitan area of Lisbon (2020). To the best of our knowledge, the only estimates concerning Italian regions are those provided by Pesce and Succi (2016) and by Salvucci and Lombardo (2016 and 2017).

By extending Pesce and Succi (2016), this paper focuses on two Italian northern regions, Liguria and Lombardy. Regions (classified as NUTS 2 in the Eurostat nomenclature of territorial statistical units) are administrative units of particular interest for our analysis, as -starting from the early 1990s- the public responsibility to deliver health services has been increasingly decentralized towards them. An implication of this decentralization process is that health expenditures generally represent the main item in regional budgets (another implication, however, has been increasing territorial inequalities in the provision of health services: see Garattini et al. 2022).

While we plan to extend the present analysis to other areas in the future, a few words to explain on why we deal with the Liguria and Lombardy regions are in order. Actually, the work origins from a convention signed in 2016 between Istat (the Italian National Institute of Statistics) and the Regional Health Agency of Liguria. As a result, the Istat regional office located in Genoa contributed to implement a regional information system for public health, by populating the database with socio-demographical data on determinants of health in Liguria and other relevant information like estimates of ED accessibility. Regardless of these institutional arrangements, we believe that investigating emergency care in Liguria may provide useful insights on whether and how differences in accessibility to health services affects inequalities in living standards. Indeed, the region is characterized by a very elderly population, which notoriously affects the demand of emergency services (Dufour et al. 2019). A large and densely populated region like Lombardy is another interesting case study *per se* and a useful benchmark, in the light of the relatively high quality of its health services (Bruzzi et al., 2022, compute a multidimensional quality index to compare the performance of regional health systems in Italy in 2015; they find that Lombardy ranks first).

Finally, before discussing methods and results, we want to highlight that an interesting by-product of our contribution is showing how researchers, by using standard hardware resources, may rely on a free, open-source, documented and powerful software toolchain to operate on large, public geographical datasets. This allows for easy reproducibility of study results.

Andrea Marino, ISTAT, Italian National Institute of Statistics, Italy, anmarino@istat.it, 0000-0002-9854-7885
Marco Pesce, ISTAT, Italian National Institute of Statistics, Italy, pesce@istat.it, 0000-0002-8926-7128
Raffaella Succi, ISTAT, Italian National Institute of Statistics, Italy, succi@istat.it

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2. Evaluating travel distances to EDs: methodology and data

Census enumeration areas (CEAs) represent our main geographic unit of analysis. Such areas are defined for statistical purposes and represent partitions of a municipality (“Comune”), the smallest administrative unit in Italy (in turn, municipalities are part of a region). Latest population data at the CEA level are currently available only from the 2011 Census and are provided by the Italian National Institute of Statistics (Istat). According to such information, in 2011 the number of CEAs in the Lombardy and Liguria regions were equal to 53,174 and 11,054 units, respectively.

Fig.1. Italy

Table 1. Regional population: distribution by estimated travel times to the nearest ED

	Population data (2011 Census)		*Accessibility to emergency care services*				
	Total	Density (*inhab. / km²*)	Population distribution (%) by travel times to the nearest ED				
			<15'	**15'-30'**	**30'-45'**	**45'-60'**	**>60'**
Liguria	1,570,694	289.9	87.2	11.1	1.5	0.2	0.1
Lombardy	9,704,151	407.0	89.0	10.5	0.3	0.1	0.1

The algorithm determining travel times to the nearest ED relies on a multi-step strategy. In the first step, it computes the minimum driving time from the CEA under scrutiny to a given ED by comparing the distances of all existing routes linking the two locations. Such a computation is done for all EDs located in the same region as the CEA. This allows singling out the closest ED (and the implied travel time). Finally, these steps are repeated for all CEAs, leading to the construction of a distance matrix containing information on travel times from each CEA to the nearest emergency care service.[1]

More in detail, in order to accomplish the tasks outlined above, we have drawn on a bundle of official as well as crowdsourced data and we have relied on open-source software to process them. From shapefile format maps we have computed the latitude and longitude coordinates of the centroid of each CEA. Such a centroid represents in our calculations the starting point of each travel distance from a given CEA to the existing emergency care facilities. Moreover, from open data sources we have been able to geocode a total number of 122 health facilities supplying in 2013 emergency care services, 103 in the Lombardy region and 19 in Liguria.[2]

Solving the routing problem (i.e. determining the fastest and/or shortest path to an emergency care facility) requires: 1) a routing graph connecting each location (CEA) to all EDs; 2) an algorithm computing (and comparing) travel distances of each possible path. The international crowdsourced project *OpenStreetMap* provides us with a routing graph. The *Open Source Routing Machine (OSRM)* engine and its related tool *OSRM Distance* allow the search of minimum road paths (documentation concerning *OSRM* may be found in Luxen and Vetter, 2011). An instance of *OSRM* backend server was built for offline processing of data extracted from the *OpenStreetMap* database. This significantly reduces computing times by avoiding limitations that even freely accessible online servers may impose upon receiving high-frequency/high-bandwidth queries (note that in the case of a large area such as the Lombardy region, the whole distance matrix contains almost 5,5 million records).[3]

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[1] Our estimations of ED accessibility take into account driving times only. We lack information on the availability of alternative modes of transportation (such as helicopters). We are also aware that in many cases patients arrive at EDs by their own transport. Furthermore, they may not choose the closest emergency facility based upon subjective preferences or common information about health services quality.

[2] The definition of ED used throughout the paper includes only the following categories of medical centers: a) “Dipartimenti di Emergenza e Accettazione (DEA)” ; b) “Ospedali sedi di pronto soccorso”. It rules out, however, the so called “Punti di primo intervento”. These differ from the categories mentioned above in some important respect; in particular, they may be not open 24 hours a day and provide treatment for less severe emergency cases. Detailed information and definitions are available in the website of the Italian Ministry of Health: www.salute.gov.it.

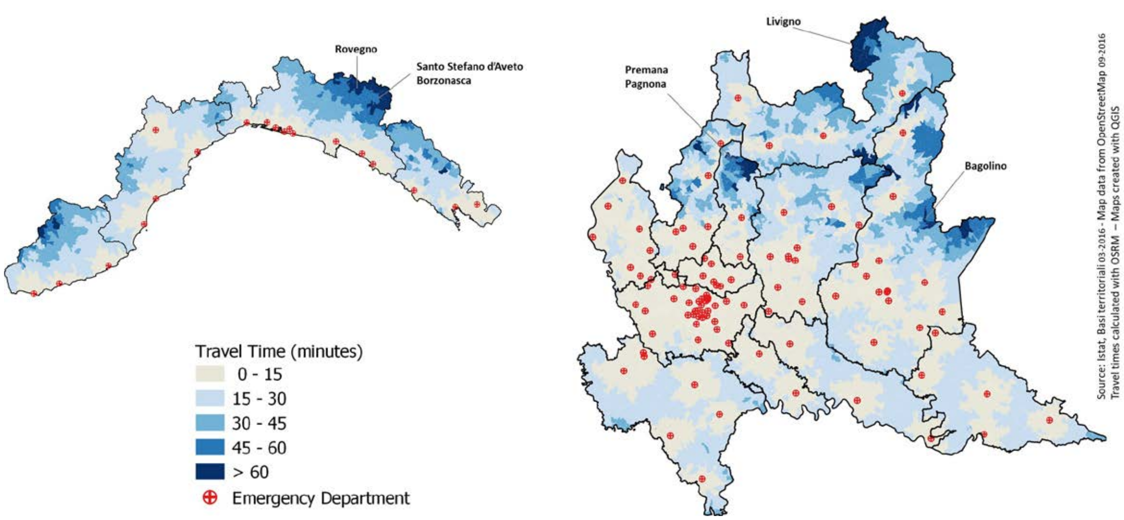
[3] Data from *OpenStreetMap* (www.openstreetmap.org) can be obtained as file archives from multiple internet repositories: this allows for completely local, offline processing through *OSRM* (https://github.com/Project-OSRM). Thus,

Accessibility is measured as the driving time required to travel through the fastest path from the centroid of each CEA to the nearest emergency care facility. The calculation of distance (in time units) assumes as a starting point the road junction, which is closest to the centroid. Also, travel times are computed by assuming that speed corresponds either to known speed limits (when such an information is available) or to standard speed limits for urban and non-urban roads. Moreover, the computation assumes optimal traffic conditions (no time losses due to either traffic jams or traffic lights).

3. Evaluating travel distances to EDs: results

Figure 2 depicts our estimates of the distribution of the population by different ranges of travel times to the nearest ED. Clearly, when emergency care is needed, arrival at ED facilities should occur in the shortest possible time. A different, but related, issue is what are the "critical" travel time thresholds, which have to be respected in order to ensure adequate treatment. From the patients' point of view, this question can only have a case-by-case answer. When setting targets to plan or evaluate public health systems, a common threshold corresponds to 60 minutes (Lilley et al., 2019). Indeed, this is a policy-relevant threshold in the Italian case too.[4] Yet, there are at least two important reasons to present also results based on alternative (and more restrictive) time cut-offs. First, as Lilley et al. (2019) themselves point out, the choice of setting as a threshold the so-called "golden hour" is "not supported by strong-evidence base". Secondly, since in many cases patients do not arrive at EDs by their own transport, a complete evaluation of driving times to the nearest ED should take into account also distances between where people live and where ground ambulance depots are located. As accurate information on this is missing, a sensitive analysis accounting also for lower time thresholds is in order.

Fig.2. Estimated travel times to the nearest ED in Liguria and Lombardy by CEA (with ED locations and province borders)



every step of the process remains under direct and granular control, as it is not tied to cloud services constraints (such as tariffs or usage limits) nor to undocumented, run-time variations in server-side behaviour that may affect final output. Being reliant on origin-destination tables, such a methodology may be computationally demanding in case of large areas, but it is also scalable as more efficient hardware becomes available (e.g. through multi-core processing that OSRM exploits natively).

[4] Italian administrative laws concerning accessibility to emergency care define as particularly disadvantaged (i.e. most remote) areas those with travel times to the nearest emergency care facility higher than 60 minutes (Ministero della Salute, *"Regolamento sugli standard dell'assistenza ospedaliera"*, Decreto n.70, 07/04/2015).

With respect to the 60 minutes threshold, the actual location of emergency-equipped hospitals in 2013 was able to yield a high population coverage rate in both Liguria and Lombardy; indeed, the share of the population living in most remote areas was about 0.1% in both regions. However, some regional differences emerge when setting lower critical time thresholds. For instance, figures reported in Table 1 imply that in the Lombardy region the share of the population facing travel times beyond 30 minutes is 0.5%, whereas the same percentage grows up to 1.8% in Liguria. Also, the share of the population whose access to the nearest ED lies within 15 minutes is 89% in Lombardy and around two percentage points lower in Liguria. These inter-regional differences seem moderate and come to no surprise given that accessibility generally grows with population density (see Table 1; see also Lilley et al., 2019, on this). Note finally that -in both regions- CEAs with low accessibility are located in mountain areas (some municipality names corresponding to these CEAs are reported in Figure 2).

Population coverage rates reported in Table 1 may not accurately describe the current situation, as the number of EDs has changed in the last years. At the time of writing (June 2022) we lack all the data required to re-run our estimation procedure on updated information. While leaving this exercise for future research, here we give a clue of how the picture may have recently evolved in Liguria, which has undergone a sizable reduction in the number of EDs (from 19 to 12, all of which are now located along the coast). To do so, we have used 2021 population data available at the municipality level and assumed that population uniformly grew within each municipality between 2011 and 2021. This provides us with an estimate of CEA-level population in 2021. By combining this with updated information on EDs and travel distances, we find that the decrease in EDs has generally implied a worsening in coverage rates; e.g., according to our estimates, the population share currently facing driving times higher than 30 minutes is about 3.5%, i.e. it has doubled with respect to the situation represented in Table 1.

4. Population living standards and accessibility to emergency care

A timely provision of emergency care services throughout the national territory appears a particularly challenging goal nowadays. The tighter budget constraints the Italian NHS has to cope with impose a strong efficiency-equity trade-off. Scale economies and the high concentration of the population in urbanized areas may push regional policymakers toward a higher centralization in the supply of ED services, which comes at the cost of higher (within-region) inequalities. To understand why, it is worth recalling some mechanisms through which differences in accessibility may lead to higher inequality. To begin with, the literature has shown that differences in accessibility affect individual behavior due to a "*distance decay effect*": compared to people living closer to EDs, those residing in more remote areas are less likely to demand certain emergency care services even when these are equally needed. Other studies point out to the existence of an "*inverse care law*": areas characterized by law accessibility often coincide with the more socio-economically deprived ones (i.e. with those needing social and health services most). Differently stated, "the availability of good medical care tends to vary inversely with the need for the population served" (Hart, 1971).

From a normative point of view, regional emergency care services should be planned in a way to prevent the rise of *health inequities* discriminating certain population subgroups.[5] Such a goal requires not only accurate evaluations of physical accessibility to EDs but also a deep knowledge of some social characteristics of the population, which may contribute to give rise to health inequities (whether in combination with low accessibility or in an independent way). It is well known that socio-demographic and economic factors such as age, sex, ethnicity, education and occupational status (to mention a few) are significant social determinants of health and emergency care utilization (Marmot, 2005). Moreover, caring for more vulnerable people regardless of their numerical importance is one of main tenets underlying the Sustainable Development Goals (the so-called "*Leave No One Behind*" principle).

In order to study whether and how socio-demographical and economic factors change with

[5] *Health inequities* correspond to *health inequalities* which are "preventable and unnecessary" and thus "could be avoided by reasonable means" (Arcaya et al., 2015).

differences in accessibility, we have combined our estimates of travel times at the CEA level with some information coming from the 2011 Population Census. First, we have partitioned the territory of each region according to given thresholds of driving times to the nearest ED (such thresholds are determined by 15 minutes intervals, with the ">60 minutes" category representing a residual class). Secondly, using census data, we have computed the values of a set of socio-economic indicators referred to the subpopulations belonging to such time intervals. These variables are: the ratio of people aged 65 years and more to the total population, the population share of foreign inhabitants, the ratio of less educated people (i.e. those who do not hold at least a secondary school degree) to the population aged 6 years and more, the ratio of single-member families to the total number of families, the unemployment rate.

Table 2. Socio-demographic characteristics and ED accessibility (percentage values)

	Liguria						Lombardy					
	Subpopulation weight within travel time categories					Total	Subpopulation weight within travel time categories					Total
	< 15'	15'-30'	30'-45'	45'-60'	>60'		< 15'	15'-30'	30'-45'	45'-60'	>60'	
Age >= 65 years	27.4	27.0	31.9	40.5	35.7	27.4	20.8	20.4	24.6	19.0	18.3	20.8
Foreigners	7.3	5.4	5.6	4.5	2.6	7.1	9.8	9.3	6.8	10.0	3.9	9.8
Single-member family	40.3	42.2	53.7	63.6	60.8	40.9	32.2	30.0	39.7	38.4	29.4	32.0
Low education	54.8	62.2	66.6	70.6	69.7	55.9	56.7	65.8	67.4	64.5	72.5	57.7
Unemployment rate	8.0	6.9	6.2	6.7	5.4	7.8	6.9	6.6	5.1	4.2	3.7	6.8

Table 2 provides a descriptive analysis of the results obtained. As it may observed, populations groups living in the remote (45-60 minutes) and most remotes (>60 minutes) areas in Liguria appear more vulnerable; for instance, the share of less educated people in these areas is around 70%, compared to a regional average of 55.9%. Also, the share of people aged 65 years and more achieves 40.5% and 35.7% of the total population living in remote and most remote areas, respectively; this is again clearly more than the regional average (27.4%). Something similar happens for single-member families. In Lombardy, distributions tend to be flatter. However, we observe that in the most remote areas the incidence of less educated people is higher than elsewhere, while the share of people aged 65 years and more it is only 18.3% (mainly due the upward contribution coming from mountain zones). Overall, the descriptive analysis of Table 2 seems to show that in Liguria differences in accessibility to ED services actually represent a further source of health inequalities that interacts with usual social determinants.

A straightforward question is how much distances and social determinants of health inequalities are related. Answering this question with CEA-level data is not an easy task. To see why, note that many census areas are very thinly populated, so that the socioeconomic indicators we consider may take on rather unusual values (think e.g. of unemployment rates equal to 0% or 100% in CEAs with only one inhabitant). To overcome such a problem, we have computed correlations at the municipality level (after computing population-weighted averages of travel distances measured at the CEA level). Results reported in Table 3 indicate that travel times are positively correlated to some social determinants of health inequality (like the incidence of elderly and less educated people, and the share of single-member families). Such a result (which holds for both Liguria and Lombardy) is worrying as it implies that the "*inverse care law*" may actually be at work and deserves further investigation in future work.

Table 3. Correlations between socio-economic indicators and population-weighted average travel times at municipality level

	Age>= 65 years	Foreigners	Single-member family	Low education	Unemployment rate
Liguria	0.480***	-.043	.588***	.517***	-.158**
	(.049)	(.054)	(.039)	(.047)	(.063)
Lombardy	.225***	-.048*	.326***	.427***	-.064**
	(.025)	(.086)	(.023)	(.022)	(.028)

*Bootstrap standard errors in parentheses under correlation values (9,999 replications). Significance levels: *** p < .01; ** p <.0.05; * p < .1*

5. Summary and conclusions

Timely access to emergency care services is a relevant determinant of health inequalities; thus, a geographically detailed evaluation of accessibility is a necessary step in order to design effective policies counteracting such inequalities. In order to perform such a task, our study proposes a methodology, which should be appealing for many reasons: 1) it relies on open data and open-source software; 2) it is computationally efficient; 3) it is easily interpretable. Results show that health inequalities stemming from socio-economic differences may turn into health inequities due to differences in accessibility. An obvious direction for future research would be using updated information on EDs and extending this work to other areas. More accurate estimates of accessibility should take into account the possibility that -in some cases- people needing emergency care services be transported to EDs of other regions. Also, our analysis of how differences in accessibility affect health inequities might be extended by employing more sophisticated techniques of multivariate statistics and also by relating distances to composite indices of social deprivation.

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