

# Computing 15MinCityIndexes on the Basis of Open Data and Services

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**Abstract.** Despite of the large discussions in the area of city strategies, the effective compliance assessment of each city area with respect to 15-Minute City concepts are still not clear in terms of computation. A huge amount of aspects have to be taken into account, such as: Housing, Govern, Safety, Culture and Cults Services, Environment, Slow Mobility, Fast Mobility, Sport, Economy/sustainability, Food, Health, Education, Services, Entertainment. Each of them may be assessed by taking into account a large number of factors and features. In this paper, 15MinCityIndexes model and its computability approach have been proposed. The proposed model is based on 13 different functions and addressed several features. In addition, the model has been produced by using a method that can be exploited to add more factors and details to the model when other kind of data may be available instead of those we found in our case. It has been produced and validated on Florence metro area which includes multiple cities and rural areas. The model and tools are accessible on a public online dashboard. The 15MinCityIndex approach described in this paper conquered the first place award and grant of the international ENEL-X open data challenge 2020.

**Keywords:** 15Minute Index · Smart city · Sustainability · Computability · Decision making

## 1 Introduction

In the context of Smart Cities there is a strong push on shaping cities to be more livable and sustainable for the citizens. The trend has been reinforced with the arrival of COVID-19 pandemic which led to lockdown limiting mobility of city users constraining them in their neighborhood. Thus, the 15-Minute City concept of Carlos Moreno [15] has been revitalized. On that path, a similar trend of "*chrono-urbanism*" has been followed by others whose proposed models for improving quality of life in cities. For example, the 15-Minute walkable neighborhood of [17] and the 20-Minute City model of [10]. They were proposed as viable models for modern cities to address their underlying challenges. Some cities followed this kind of strategies according to their vocation, for example, becoming a pedestrian city, a bike city, saving energy, etc. Without to arrive at

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a drastic decision, many cities have invested more resources in sustainability, services decentralization/distribution, etc., in order to reduce the mandatory movements of city users among the different part of the city. One of the effects has been a strong increment on the usage of slow and more sustainable mobility and to local/proximity services (selling more bikes for moving, and pet for walking), also forced by a strong reduction of mobility, parking, etc. for the lockdown due to COVID-19 pandemic [1, 3].

In more details, the concept of Carlos Moreno in the first paper of 2016 aimed at providing to city users all their basic essential services at no more than 15 Minute by walk or biking from the point in which they live [15]. Presently Moreno et al. are supporting the concepts a higher quality of life, which can be fulfilled by means of six urban/social **Functions** namely: *living, working, commerce, healthcare, education and entertainment*. For each of them, there is the need to be compliant with **Features** such as *proximity, diversity, density* and *ubiquity*. For example, working at short distance from one live, and with the opportunity of getting in the area different services to satisfy your needs. From the technical point of view, a number of studies have tried to assess *pros* and *cons* of having a 15-Minute City. For example, assessing the global cost and time reduction for the city users due to the possibility of having all in the short range from where they live. The total amount of time and money spent in the whole city for these activities is huge: tens of hours waste on traffic per person per year in US [14]. In addition, the reduction of traffic also produces a relevant reduction of pollutant on NOX and CO2 [16].

In [15], Carlos Moreno proposed a "modified 15-Minute City" framework with different 4 features: *proximity, diversity, density* and *digitization*. In some measure the digitization dimension has been an indirect observation that the ubiquity has been overcome by the technological solutions put in place on the push of pandemic, thus creating a sort of "*new normal*" conditions of ubiquity. The digitization also copes with the level of exploitation of ICT solutions including open data, IOT, smart city technologies, last mile delivering, 5G, etc. [2]. The *density* has been related to the number of people per square kilometer. This means that in substance the six functions have to be proportioned to the number of users in the area. The *proximity* has to cope with the distance, so that 15-Minute City can be regarded as a measure of the "*distance by waking*", while biking the real distance in terms of meters would be higher. In addition, the covered distance may be related to the age of the person, and to the contextual conditions. A mom with a baby would not be fast in moving such as a teenager. In substance, the proximity has to cope with both space and time, and accessibility of services; and it could be very complex to be actually estimated since the cities may have infrastructures that may lead to the impossibility to reach a very close area for the lack of walkable paths (barriers, e.g., the highways, the rivers, the reserved roads). The *diversity* describes the needs of having an assortment of the services which should be accessible in the area. The diversity should be related somehow with the social needs and culture of the city users. They have to be satisfied of the diversity provided.

Despite of the large discussions about city strategies, the effective compliance assessment of each city area with respect to 15-Minute City concepts are still not clear in terms of computation. If their simple computation from data is possible. The huge amount of aspects to be taken into account for each Function and Feature is impressive, and the

cardinality (combination) is large. Please note that, the assessment could range from the identification of services to big data analysis taking into account all services details: capability, hours of opening, age target, quality of service, cultural target, etc. In most cases, the proposed assessments have been based on questionnaires posed to city users in some local areas, and thus are far to be objective and computable in wide areas as provinces or regions.

In [17], the proximity problem has been addressed taking into account the diversity of city user profiles in terms of their capability to cover the "15-Minute" distance. In particular, also the travel time computation may hide complexity due to the presence of barriers and diversity in routing according to the travel means [5]. The study proposed by [17] put the evidence that significant social inequalities exist in the 15-Minute City walkable neighborhoods. Spatial regression shows that the 15-Minute walkable neighborhoods score is positively correlated to proportion of adults and seniors, and it is negatively correlated to proportion of children population and temporary city user (visitor, tourist, commuters, etc.). On the other hand, children may not need to have access to services for adults. The approach proposed by [17] and also those based on detailed computation of walkability [12, 18] resulted to be very complex to be scaled on large area, and may need a continuous update for changes of road structure of the city. In [6], a number of indexes have been defined to assess the reachability, attractiveness, and the permeability of each city area from the city. Also in this case, the large region scalability is not clear. In [9], the network analysis has been performed for assessing metrics such as network betweenness and centrality of the road network of the city. This allowed to identify critical points and nodes in the road network. In [13], the 15-Minute City concept has been adopted as life circle in which a number of indexes can be computed on the basis of the presence of services (identified as Point of Interest, POI). The Functions have been on: *gov, roads, commerce, dining, edu, medical, entertainment and pension.* The approach aimed at providing suggestions for city planning.

In this paper, we are proposing a computability approach for the assessment of cities/area compliance with respect to the 15-Minute concept. It can be used for the assessment, raking and planning/restructuring of city services. The proposed computational model allows to produce an index to assess 15-Minute concept compliance for each point of an area that has been called **15MinCityIndex**. The index is based on a number of subindexes, each of which models a **Function** and its computation is based on a set of **Features**, thus providing a computational semantic to the 15-Minute concept. Please note that with respect to the state of the art indexes reported above, it addresses more functions and domains, and produces a unified **15MinCityIndex**. The proposed model has been produced and validated on Florence metro area which includes multiple cities and rural areas. The **15MinCityIndex** described in this paper conquered the first place award and grant of the international ENEL-X open data challenge 2020 [11].

It can be computed in different areas and can be easily extended to take into account data and aspects according to the data availability of the region/province in which it is applied. The processes of data collection, spatial reasoning and computing have been performed thanks to the Snap4City infrastructure in Tuscany area and in Florence in particular (https://www.snap4city.org) [4]. Snap4City is providing 100% open source tools and free registration on several different organization smart city areas.

This paper is organized as follows. In Sect. 2, the Functions considered and the corresponding subindexes are discussed, performing a comparison with former proposals. Section 3 reports the computational model of the subindexes. Section 4 describes the tool for the usage and validation of results which can be freely accessed on-line. Conclusions are drawn on Sect. 5.

## 2 Functions' Subindexes

The 6 Functions identified by Moreno and listed above are in somehow not adequate to assess the complexity of an area. In particular, the living Function is too generic and includes a lot of other aspects that should be addressed separately to better understand the area/city ranking. For this reason, additional aspects have been addressed with separate views in the model proposed as clarified in Table 1. The first step has been the identification of features which can characterize the 15MinCityIndex. The first point has been the literature and the second the taxonomical experience we had in defining the Km4City ontology for smart city [7]. As a result 13 Functions have been defined as follows.

**Table 1.** Comparing 15MinCityIndex

| Moreno functions | Li et al., 2019 [13] | 15MinCityIndex subindexes |
|---|---|---|
| *living* | | Housing viability |
| | *Gov* | Govern Services |
| | | Safety Services |
| | | Culture and Cults Services |
| | | Environment Quality |
| | *Roads* | Slow Mobility Services |
| | | Fast Mobility Services |
| | *[Medical]* | Sport Services |
| *working* | | Economy/sustainability |
| | *pension* | |
| *commerce* | *commerce* | |
| | *dining* | Food Services |
| *healthcare* | *medical* | Health Services |
| *education* | *edu* | Education Services |
| *entertainment* | *entertainment* | Entertainment Services |

In **15MinCityIndex**, the distribution of commercial activities has been exploited into Economy and thus we mapped on Moreno's commerce only on Food Services for sustainability. Please note that with the on demand delivery most of the issues related to

commerce are losing their relevance. The sport could be mapped on living aspects as well as on healthcare or entertainment according to the concept of the index. For these reasons we kept the aspects separate. As a result, the proposed 15MinCityIndex is capable to describe the city/area livability and self-sustainability with respect to the inhabitants of the area with a higher level of details. The challenge remains the computability of the index as described in the rest of the paper.

In the following, the **13 Subindexes/Functions of the 15MinCityIndex** are described positing the attention to the aspects of their *data sources, density, diversity, normative/reference values or KPI, proximity.* Moreover, the issues regarding the *computability* of the indexes are addressed in a successive section of this paper.

1. **Environment Quality**. In this case, the aim is to assess the environmental quality of the area for living. To this end, good indicators can be: EAQI (European Air Quality Index), quality of water, presence of green areas/gardens (which can be recovered from municipality or from Copernicus Satellite data with some limitations), noise level, specific pollutants (NO2, CO2, O3, PM10, PM2.5, etc.). For most of them, recommended values are provided at the EC level. Please note that, most of the pollutants are also taken into account by the EAQI which is based on PM2.5, PM10, NO2, O2 and SO2, so that, the EAQI supersede them.
2. **Economy/Sustainability**. This subindex aims at assessing the economic sustainability of the area, which is a sort of demand-vs-offer index. In practice, the area is self-sustainable if the potential amount of working places (on commercial and industrial) compared to the workforce available in the area is satisfactory to ensure the economic well-being of the dwellers. To perform this estimation the knowledge of the number of people living in the area is fundamental, considering those that are in the age of working and retired. In addition, the offer has to be computed on the basis of the shops, services, industries, etc., of the area. This means that, census data and commercial/economic data of the area have to be accessible. Commercial/industrial services are in most cases accessible as POI. On the other hand, their capability in terms of personnel could allow to be more precise, and it may be available from the chambre of commerce. A secondary index could be considered assessing at the level of municipality if the total salary of the area (including retired people) could be enough for the sustainability of the whole population of the area.
3. **Housing Viability**. It should be an index to assess the quality of houses in the area. Another view could be obtained on the basis of the age of the building. A simple approach can be performed on the basis of the prices for square meters of the real estate market, which is also related to the demand of living there. The average price/m2 in the area can be taken as a sort of index of quality, and it should be normalized with respect to the number of city users living in the area. Diversity aspect on this topic could lead to have a range of different houses in terms of prices.
4. **Health Services**. In this case, the subindex is focused on assessing the availability of health services (*diversity* as: pharmacies, private and public hospitals, labs, studio of doctors, presence of defibrillators, etc.) in the area of interest with respect to the number of users of the area. On this regard, there are some *KPI* provided by the EC. For example, for the coverage of the pharmacies in terms of potential clients of the area. For instance, a pharmacy every 3000 people for Italian govern, 500

hospitals' beds every 100.000 inhabitants, 80 dentists per 100.000 inhabitants, 1.6 hospitals per 100.000 inhabitants, etc.

5. **Food Services.** This subindex is focused on assessing the presence of food distribution and services in the area of interest with respect to the number of users of the area. The food distribution can provide a large *diversity* as groceries, restaurants, small food shops, supermarkets, etc. Most of the data can be taken from Open Data, chambre of commerce and POI. The critical aspect could be to take into account of the capability of each food service. National or regional average could give the reference values.
6. **Education Services**. This subindex is focused on assessing the presence of education services in the area of interest with respect to the number of users of the area which should be in the age of school. The educational services are: schools of any level, universities, private schools, etc., different languages and cultures. Most of the data can be taken from Open Data, and POI. More complex could be to get the capability in terms of students of each educational infrastructure. National or regional average could give the reference values.
7. **Slow Mobility Services**. This subindex should represent the suitability of the area to facilitate the local mobility. It could take into account: walkability, presence of sidewalks, number of Km of roads (that can be used for walking and biking), presence and number of cycling paths, availability of bike/cart sharing, number of sharing station for short range travel, and may be as critical point the presence of barriers such as bridges, highways, etc., which can limit the walkability. Please note that good slow mobility services can facilitate the movements in the area, and this may reduce the needs of taking less sustainable travel means. On the other hand, having a good rank on most of the subindexes (taking into account of services in the area) it would reduce the needs of exiting from the local area by using a private or public travel means to access at the not accessible services. Road information can be recovered from Open Street Map, OSM, as well as from the local govern.
8. **Govern Services**. This subindex is focused on assessing the availability of local govern services in the area of interest with respect to the number of users of the area which are in the age of use/need them. These services are: municipality services, taxes office, etc. Most of the data can be taken from Open Data, and POI. National or regional average could give the reference values.
9. **Safety Services**. This subindex is focused on assessing the level of safety services in the area of interest with respect to the number of users of the area. These services may have a large *diversity* and are: local and national police office, security office, number and position of monitoring cameras, fire brigade, civil protection, level of light and presence of smart lights, availability of alarm buttons on the area, coverage of security services by phone and Apps, etc. Additional information could be taken into account for marking the area on the basis of other risk factors such as: flooding, landslide, terrorist attack, risk level for the buildings, criminality (distribution of incidents and of criminal actions), etc., and on resilience capability [8]. Most of these details can be obtained from civil protection and local govern offices, data can be taken from Open Data, and POI. National or regional average could give the reference values.

10. **Culture and Cults Services**. This subindex is focused on assessing the presence of cultural and cults services in the area of interest with respect to the number of users of the area. The *diversity* of services should take into account: museum, monuments, vista points, mausoleum, churches of any kind (may be of cults in proportion to the demand of the city users of the area), libraries, book shops, etc. Most of the data can be taken from Open Data, and POI. National or regional average could give the reference values.
11. **Entertainment Services**. This subindex is focused on assessing the availability of entertainment services in the area of interest with respect to the number of users of the area. These services are: theaters, auditoriums, cinemas, game rooms, etc. Most of the data can be taken from Open Data, and POI. National or regional average could give the reference values.
12. **Fast Mobility Services**. In this case, the subindex aims at assessing the presence in the area of services for moving out of the area for medium (city busses, area busses) and long distances (railways, airports, highway joint), with respect to the number of users of the authorized age to use them. For the diversity, in addition to the above info, services such as the presence of fuel stations, the size of bus stops and railways stations, long range recharging stations, etc., should be taken into account. Most of the data can be taken from Open Data, and POI. National or regional average could give the reference values. Public transportation data (bus stops, bus lines, train stops, etc.) can be recovered from GTFS and/or Transmodel files which are generated by the operators.
13. **Sport Services**. This subindex is focused on assessing the availability of sport services in the area of interest with respect to the number of users. These services are: sport facilities, gyms, training infrastructures, arenas, swimming pools, etc. Most of the data can be taken from Open Data, and POI. National or regional average could give the reference values.

## 3 Computing the 15MinCityIndex

The implementation of the general concept of the 15MinCityIndex should lead to provide a dense heatmap in which all the points of an area are assessed in terms of Function aspects and on which the city/area officer can click to pick the values of the indexes in all parts of the area under analysis. This approach allows them to perform the assessment and to decide in which area the investment have to be performed, and on which Function. The present version of the 15MinCityIndex is mainly focused on city area, while a similar approach can be adopted for the computation of the index also on rural and industrialized area.

According to the above performed description and analysis, the computability of subindexes has to pass from the collection of the above mentioned data. The first step is to make a decision on the spatial resolution since it cannot be realistically computed for each civic number. To this end, we have identified a grid of points with 700 m of distance northings and eastings (y × coordinates). The grid of points determined a grid of circles with 400 m of ray which are partially overlapped. Once the grid is estimated a number of normalization factors has to be computed. The normalization factors are used for the

computation of the subindexes, and the subindexes are used for the computation of the 15MinCityIndex. In the next subsection the single steps are presented. The following schema describes the whole process which has been implemented on Snap4City platform to accelerate the production.

**Computation of the grid 700 × 700** m and center points. The basic element of the grid is a circle with ray of 500 m in each grid point thus taking a diagonal close to 1000 m. This means that they may be partially overlapped on (y × coordinates) and adjacent on the center point into the area in which the corners are the grid points.
**Data gathering/ingestion and geolocalization** on knowledge base Km4City (a classic GIS may be used as well, may be with more complexity), for the whole area of interest: (a) collection of POI data from Open Data; (b) collection of economic aspects such as PIL per area or per region; (c) collection of the normalization factors such as: density of population per age, etc.; (d) computation of the normalization point per grid area.
**Computing each subindex** and **for each center of the list of points**: (a) computation of the data performing geo spatial queries on the Snap4City KB; (b) normalization of data of the subindex, to align the distribution (see later for details); (c) computation of the subindex on the basis of the identified data; (d) production of the Heatmap;
**Computation of the 15MinCityIndex**, for each grid area: (a) computation of the index by integrating subindexes; (b) production of the Heatmap for the 15MinCityIndex.
In the next subsections, the most relevant steps are presented.

### 3.1 Computing Normalization Factors

On the basis of the above presented subindexes the most relevant normalization factor is the number of people living in each area. This information can be recovered from census data. Moreover, the distribution of civic numbers of houses and the size of the building can help in this sense.

### 3.2 Computing Subindex

The computation of the subindexes is almost similar for most of them. In the following, we assume the availability of the data described in Sect. 2 for each subindex and their loading on Snap4City KB where is possible to perform geospatial queries in the proximity of the grid points as described above. The subindexes can be visually accessed on Snap4City Dashboards such as: https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjkzOA== and the original data on ServiceMap http://firenze.km4city.org/.

The subindexes can be grouped in 5 categories on the basis of the computational model adopted for their production. The main reasons to have different models is due to the data sources and to their aim. And in particular those categories are:

- **A)** environment quality: quality of the environment in which one is going to live.
- **B)** economy/sustainability: this is focused on assessing the sustainability of the area matching the offer vs the demand of work, in first approximation.

- **C)** housing viability: this is focused on assessing the affordability of having a house of reasonable quality.
- **D)** health services, food services, education services, govern services, safety services, culture and cults services, slow mobility services, fast mobility services, entertainment services, sport services. They are focused on assessing the availability of services.

**Environment Subindex** (A) is computed combining EAQI and the square meter of green per inhabitants in the area. The EAQI is typically provided in terms of Likert scale from good to very poor. We reported all in Likert scale from Good (5) to critical (1). There is a normative that requests to have at least 9 square meters for citizen, and on the basis of that we have scaled by K to get satisfactory when that threshold is reached (Fig. 1).

$$\text{SubIndex(env)} = (\text{EAQI} + \text{K GreenAreasSM}/\#\text{Inhabitants})/2$$




**Fig. 1.** Likert scale heatmap color index adopted

A similar approach has been adopted for each subindex and for the general 15MinCityIndex. Thus reporting all values on Likert scale from 1 to 5. This scale is able to give an immediate information about the positioning of the area with respect to the other area of the region/territory at the expense of resolution. On the other hand, a full resolution values would not be needed to identify critical areas.

The **Economy subindex** (B) is focused on assessing the economic sustainability of the area matching the number of people able to work with the job offer of companies situated in the area. For this purpose, a simple counting of all commercial and industrial activities POI on Snap4City ServiceMap KB has been performed. The main concept is to assess the difference of the offer with respect to the demand of work. If the offer is higher than the 5% would be green, 10% blue, −5% yellow and −10% or less orange. The obtained distribution of values for the grid areas was out of the 1–5 Likert scale. This computation is performed as follows:

$$\text{SubIndex (economy)} = (\text{Offer} - \text{Demand})/\text{Demand } \%$$

$$\text{Offer} = (\#\text{industrialPOI} + \#\text{commercialPOI}) * \text{MeanNumberOfWokersPerCompanyInMunicipality}$$

$$\text{Demand} = \text{NumberofInhabitantsworkinginthearea}$$

For each specific grid area also an estimate of the available workforce has been provided assessing the number of people able to work on the basis of the population

age groups data for each municipality. The mean number of workers per company in the municipality is a data obtained from ISTAT for all municipalities in Italy.

The **housing viability** (C) is focused on assessing the affordability of having a house of reasonable quality and price in the area. To this end, in first approximation we have used the real estate quotation in each specific grid area in Euro normalized with P which is the mean affordable price for square meter. Other kind of computations based on the assessment of the building can be also valid and substantially correlated in mean value areas.

$$\text{SubIndex (housing)} = \#\text{Inhabitants/priceforsquaremeter}/P.$$

The result is a measure on inhabitants that are demanding to stay in the area. According to national average we classified each grid area in Likert scale by using the following table, assuming that a higher demand would lead to a lower viability of the area. The calibration of the table values has been performed on the basis of the actual conditions in the validation area as described in the following. Please note that the non-computable cases may occur, for example when the quotation is not present.

**Table 2.** Example of thresholds defined for tuning the distribution as in Fig. 2

| From | To | Class | |
|---|---|---|---|
| 2000 | Infinite | Orange | 1 |
| 1500 | 2000 | Yellow | 2 |
| 1000 | 1500 | White | 3 |
| 20 | 1000 | Green | 4 |
| 0,01 | 20 | Blue | 5 |

**The subindexes of Services (D)** are focused on assessing their availability in the area. For this reason, a simple counting of POI on the ServiceMap KB has been performed. In Snap4City ServiceMap POI are classified on more than 20 classes and more than 500 different subclasses [7], they are all geolocated and provide additional details and information which can be taken into account. In all subindexes of services, the distribution of classes on grid areas has been discovered to be Gaussian. For example, in the case of SubIndex(health)

$$\text{SubIndex (health)} = \#\text{inhabitants}/(\#\text{Pharmacies} + \#\text{Healthcare} + \#\text{Hospital J}).$$

The normalization has been performed on the basis of the national reference values, considering that the Hospitals are serving J times more people than Pharmacies. The obtained value of the SubIndex has been assigned to classes on the basis of a table structurally similar to that reported in Table 2, and centering the distribution on Green class as reported in the Fig. 2, **where all the distributions of the SubIndexes are reported.** Therefore, similar computations have been adopted for all the subindex of this class.

This approach makes possible the comparative assessment of the areas in different municipalities. On this regard, it could be better to perform the alignment of the distributions of the area on the basis of a large number of grid areas. For example, at least at level of province or region.

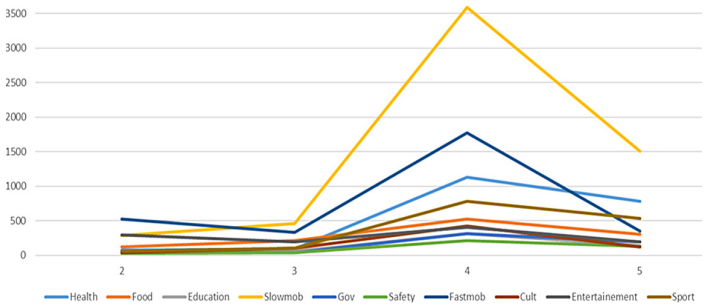


**Fig. 2.** Distributions of the areas in the Likert scale colors or the subindexes

Also in this cases, non-computable cases may occur, for example when the area does not report inhabitants or services. This happens in rural areas for which the 15MinCityIndex index has not been designed.

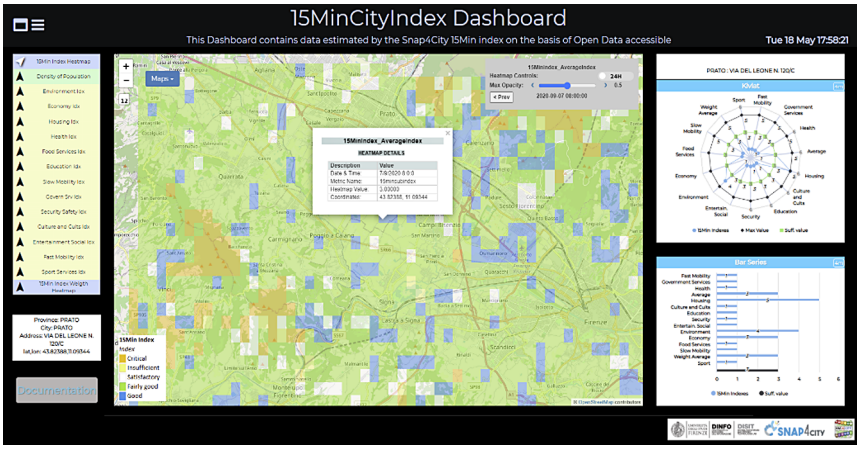


**Fig. 3.** 15MinCityIndex Dashboard on Florence area, https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjkzOA==

It should be noted that some of the subindexes may depend on complex data. For example, slow motion from the amount of Km in the grid area which has been estimated on Snap4City ServiceMap exploiting data coming from OSM (open street map), and the case of Bus Stops complexity (a bus stop may have multiple lines, and lines may have multiple rides per day, in the seasonal period in which the assessment is performed)

which has been estimated on the basis of GTFS data collected daily at regional level on Snap4City infrastructure.

### 3.3 Computing the 15MinCityIndex

The combination of the above described subindexes may produce a global 15MinCityIndex to express with a single value, the suitability of each single grid area to the concept of 15-Minute City as proposed in this paper. According to the above formulation, all the subindexes should provide values in the range of 1–5 in Likert scale, and thus also the 15MinCityIndex should be in Likert scale to be represented as a heatmap as the other subindexes.

As a remark, the subindexes may not produce values in all the points since the value may result not computable for the lack of inhabitants, or for the lack of data, or actual services. This means that the 15MinCityIndex should be computable in absence of some of the subindexes. Different possibilities for modeling the computation of 15MinCityIndex have been proposed such as the average of the subindex, the median, and the weighted average/median. The weighted approaches may be focused on assessing in different manner area which are city based with respect to those at prevalent industrialization or vegetation. Most of the subindex can be considered orthogonal independent aspects, while in reality some of them can be similar and thus one subindex could be in some measure a partial surrogate of another. At the support of the independence of the subindex we have performed a cross-correlation among them discovering that the most relevant correlation among the 156 correlation is the one between economy and fastmobility with 0.64%, the second one of SlowMobility and housing. All the others are smaller than 0.50%

As a general consideration, the production of all the subindexes in large national area can be very expensive. For example, in the area of validation we have obtained about 1750 points while in the whole Italy we have about 150.000 points. Some of the data can be collected at level of municipality which in Italy are about 8000, others at level of province (110 in Italy) or region which are 20. On the other hand, if the target is the 15Min grid areas at national level the grid would made up of 150000 points, which means 100 times heavier than what we performed for Florence.

## 4 Using and Validating Subindexes and 15MinCityIndex

In order to validate the subindex proposed it has been computed in the Florence area including city of Florence, several rural areas, and about a large set of smaller cities/municipalities such as: Prato, Signa, Sesto Fiorentino, Scandicci, Empoli, Vinci, Quarrata, etc. The whole area of observation and test presents about 1740 grid areas, for about 800.000 inhabitants. In Fig. 3, the dashboard presenting the heatmaps is reported. It has been the major tool for the validation of the solution during lockdown.

The dashboard allows to access at heatmaps of the density of inhabitants, of the subindexes (different version for different dates) and of the 15MinCityIndex in different versions. The heatmaps can be selected from the list on the left column. And then, clicking on the heatmap, the tool estimates (in a few seconds, please wait) the profile

of the selected grid area in terms of all SubIndexes and 15MinCityIndex. The results are directly shown on the right side with: (i) full address recovered from georevers the selected GPS data on KB; (ii) a spidernet diagram comparing the value with min, max; (iii) barseries with the values of the subindex for a faster control, (iv) the specific value selected from the heatmap on the popup on the map. The indexes' values are shown with a range 1–5 according to the legenda visualized on left bottom corner, where 3 is considered satisfactory, 4 fairly good, 5 Good, 2 insufficient, and 1 critical.

These solutions have been tested in a number of verification points for a number of experts that validated them comparing several points for each subindex. The selected points for the comparison have been those related to areas in which they know the service level according to the legenda, ranging from good to critical. The validation allowed to calibrate some of the distributes described in Sect. 3.

For the general 15MinCityIndex, the experts preferred the map produced by the weighted average which count twice the Functions of: economy, housing, health, slow mobility, sport, education, which have been primary need in the period of lockdown for COVID-19. It should be noted that the general 15MinCityIndex is somehow arbitrary and thus it should not be considered as a driver for making decision, but only a general representation of the mode. Therefore, we suggest using the subindex and the spidernet diagram or bar series to understand the actual status of an area.

## 5 Conclusions

Despite of the extensive discussions regarding city strategies, the effective compliance assessment of each city area with respect to 15-Minute City concepts are still not clear in terms of computation. Several indexes have been proposed in the literature for specific aspects, and many others remained not addressed. In this paper, a larger amount of aspects have been taken into account, such as: Housing, Govern, Safety, Culture and Cults Services, Environment, Slow Mobility, Fast Mobility, Sport, Economy/sustainability, Food, Health, Education, Services, Entertainment. Each of them may be assessed by taking into account a large number of factors and features. In this paper, we have proposed a computability approach for the assessment of cities/area in compliance with the 15-Minute concept. It can be used for the assessment, ranking and planning/restructuring of city services. The proposed computational model allows to produce a set of 15Minute subIndexes for each point of an area. Each subindex is a **Function** and its computation is based on a set of **Features**, thus providing a computational semantic to the 15-Minute concept. Please note that with respect to the state of the art indexes, the proposed solution addressed more functions and domains, and produce a unified **15MinCityIndex**. The proposed model has been produced and validated on Florence metro area which includes multiple cities and rural areas. The **15MinCityIndex** described in this paper conquered the first place award and grant of the international ENEL-X open data challenge 2020 [11].

The solution proposed can be computed in different areas and can be easily extended to take into account data and aspects according to the data availability of the region/province in which it is applied. The processes of data collection, spatial reasoning, and computing have been performed thanks to the Snap4City infrastructure in

Tuscany area and in Florence in particular (https://www.snap4city.org) providing 100% open source tools and free registration on several different organization smart city areas.

As final consideration, we can state that the proposed 15MinCityIndex performs in a satisfactory manner in the city areas while in the rural areas, in most of the cases they are not computable and thus the global index fails in providing a correct assessment. On the other hand, its aim is to be an instrument to assess the compliance with 15MinCityIndex in the cities. A more precise evaluation of the index could be developed in the future when more open data will be made available, an updated version could also exploit territorial satellite data to evaluate the type of area, for instance whether it is rural, industrial or city in a way to customize the parameters and the subindexes of the 15MinCityIndex, this would allow to have a more consistent assessment also with the necessary services adequacy.

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