Indices for Enhancing City Sustainability

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***Abstract*—Nowadays, city sustainability is becoming paramount to improving citizens' well-living from a social and environmental point of view. Considering the data-driven approach, having a monitor infrastructure of the city life is a building block to push further the sustainability of a city by understanding its weakness. The problem becomes even more challenging during the disaster recovery phase, where it is fundamental to effectively manage people's wellness and where it is not obvious to have any more a monitoring infrastructure to rely on. To overcome the issues mentioned above, we can leverage the data coming from different sources, which, if fed into artificial intelligence (AI) and machine learning (ML) techniques, might help to overview the state of the city's sustainability.**

Considering the aforementioned scenario, in this extended abstract, we present the work conducted in the Territori Aperti project to improve City Sustainability. For this goal, we first identified three fundamental indices namely *Air Quality*, *Walkability*, and *Accessibility* that provide an overview of the city's sustainability. Then we show how those indices can be computed in a lightweight manner leveraging ML techniques. To conclude, we discuss some points of improvement of the proposed approaches and describe some related future works.

***Index Terms*—city sustainability, walkability, accessibility, air quality**

I. Sustainability Indices

City sustainability can be approached from numerous points of view, each highlighting one particular aspect of well-living. In general, these points of view can be grouped into two broaden categories, those that capture the social aspects and those which capture environmental aspects. In any case, each possible point of view must be measured properly and it can be summarised by a relative quality index. Considering those indices we can finally have an quantitative overview of the city's *sustainability*. Hereafter we highlight three sustainable quality indices which cover environmental and social aspects.

The first index that we choose is the **Air Quality** that, as a proxy of the pollution of the area, can be considered an indicator of environmental sustainability. Nowadays, the problem of pollution has become of crucial importance especially in big cities, and good air quality is critical for maintaining healthy human, animal, and plant life [1].

Concerning social sustainability, we have instead selected the following two indices. The first one is the **Walkability** Index that measures how suitable a road is for the passage of pedestrians to move from one point of the city to another and thus access residential settlements, and public and private services and equipment [2].

The second social indicator we selected is **Accessibility** Index which is a measure of how local-level public services (i.e., schools, universities, large offices, hospitals, shopping centers, car parks, gardens, museums, theaters, cinemas, etc.) are accessible to pedestrians [3] (e.g., how many entrance are present, how well the entrance are recognisable, how the population paths are well organised).

Having high Walkability and high Accessibility indices can significantly improve the quality of life, the environment, and the economy.

Considering together the Air Quality, the Walkability, and the Accessibility indices, we can summarise into the **City Sustainability Index** which capture the sustainable critical aspects of the considered city, from both social and environmental perspectives.

In the following section, we describe more in detail how we implemented these indices in the context of the Territori Aperti project.

II. Implementation of Territori Aperti

Nowadays, a large amount of information is easily accessible and can be obtained free of charge. The availability of different sources of information allows the implementation of new applications thanks to the introduction of Artificial Intelligence (AI) techniques enabling acceleration and integrated data analysis at several information levels. In particular, the application of AI and machine learning (ML) techniques demonstrate their effectiveness in revealing patterns across different heterogeneous data types. It enables the easy discovery of the relationships between Earth Observation (EO) and in-place measurements. This means that the EO community can draw immense profit from AI and that the AI community can make an invaluable contribution to monitoring and understanding the processes and transformations taking place on our planet.

We want to remark that this work has been conducted under the Territori Aperti project, which is a documentation, training,

This work is partially supported by Territori Aperti a project funded by Fondo Territori Lavoro e Conoscenza CGIL CISL UIL and by SoBigData-PlusPlus H2020-INFRAIA-2019-1 EU project, contract number 871042. and originates from the HACK@EO L'Aquila 2021 hackathon, organized by Territori Aperti and Open Search Tech in collaboration with ESA (European Space Agency), AIxIA (Associazione Italiana per l'intelligenza artificiale) and GMatics.

and research center for sustainable territorial management with a particular focus on disaster recovery [4]. In the context of disaster recovery, the sustainability of a city hit by a natural disaster becomes even more important, given the complexity of the reconstruction process and the complex management of population's wellness. In the following, we describe in detail how we implemented each of the indices described in section I, relying on AI and ML techniques and taking into account the complexity of the disaster recovery process without needing any monitor infrastructure.

A. Air Quality Index

The Copernicus program and the new satellite constellations have significantly increased the availability of Earth observation data and derived information services, including information from complex geophysical models and measurements from in-place instruments [5].

In an urban and semi-urban environment, aerosols can undergo even daily variations due to natural causes or human activities. A measure of the variation in the quantity of the different aerosols can be obtained using satellite data to compute the **Aerosol Optical Depth parameter (AOD)** starting from radiometric measurements [6]. AOD can be considered an indicator helpful in assessing air quality. The in-place data provides the most accurate information in terms of the concentration of the measured parameters. However, the spatial variation of the parameters in a particular area cannot be measured directly from the stations on site. The main advantage of satellite EO and modeling approaches is the possibility of obtaining homogeneous information on large areas without any constraint on the stations' position. For this reason, we develop a ML model for the estimation of high spatial resolution AOD maps, starting from Sentinel-2 data [7] provided by ESA [8], and using columnar AOD measurements from ground stations in the training phase.

The results of the model, can be compared with the ones measured by in-place stations and by the Sentinel-2 satellite using the Root Mean Squared Error and the coefficient correlation as correctness metrics.

B. Walkability Index

In the context of Territori Aperti, the Walkability of the roads is evaluated using two factors, one subjective and one objective. The first evaluates the perception of physical and social security and the aesthetics of the urban landscape of the road. The second considers the presence of sidewalks and obstacles, width, tortuosity, slope, and level of maintenance of the streets. Both factors have been valued by citizens (without disabilities), assigning a value in the range from 1 to 5 to each road or portion of street. Following this evaluation we created a predictive approach that estimates the Walkability of roads (or segments of roads), producing the same pair of subjective and objective indicators in the range from 1 to 5. The input data were represented by the quality air index described previously, by roads and cross-roads shapefiles, satellite images of the involved areas, and a graph of roads[1]. The results of the model can be compared with the ground-truth represented by the values assigned by citizens, using a normalised accuracy as a correctness metric.

C. Accessibility Index

Accessibility of services is evaluated in a way similar to Walkability. Same as Walkability, Accessibility is evaluated using two factors, one subjective and one objective. The first evaluates the perception of physical and social security, and infrastructure degradation. The second considers the presence of bus stops, parking lots, architectural barriers, and the level of service's access maintenance. Both factors were evaluated by citizens (without disabilities) by assigning a value in the range from 1 to 5. Next, we created a predictive approach that estimates the accessibility of services, producing as output the pair of the two subjective and objective indicators, both in the range from 1 to 5. The input data were the same as Walkability: quality air index, roads and cross-roads shapefiles, satellite images of the involved areas, and a road graph as before. Same as Walkability, the results of the model can be compared with the ground-truth evaluation performed by citizens, using accuracy as a metric for correctness.

III. DISCUSSION AND FUTURE WORK

In this extended abstract, we presented our definition of City Sustainability and how we implemented the Air Quality, Walkability and Accessibility indices. We used open data to overcome the infrastructural problems in case of natural disasters and to re-use resources already available to increase the sustainability of systems producing them. The presented indices can be used to have an accurate overview of the city sustainability, covering some of the most important aspects of the city living. However, a continuous monitoring and improving of such indices is required for maintaining the well-living of the city population. To this aim, in Territori Aperti we want to create a City Sustainability Index comprising all the indices described above. In addition, we aim to create a dashboard showing all these sustainability indices, in an easy and informative way, both to the institutions and to the population and thus to incentive the improvement and maintenance of city sustainability.

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