Revitalizing Walkability Scores: A New Assessment Based on Accessibility

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Abstract: **Context/Purpose.** With the motivation to evaluate the suitability of a urban environment for pedestrian mobility, we revisit walkability scores from the scientific literature whose one of the most representative figure is the Walk Score, which is also commercially exploited through an eponymous website. **Methods.** This study refines the purpose of the foundations of walkability scores as a "pedestrian level of accessibility" score and mobilizes works on accessibility to simplify the computations of the score. The parameter "importance of an amenity" gains a more generic estimation method. Lastly, the scoring is proposed for different trip categories before being aggregated into a global score. **Results.** We obtain a new scoring, which we apply to a small town with a simple urban layout for illustration purposes before computing scores for a larger and more diverse area. The scores allow us to identify different urban fabrics associated with different opportunities within walking distance. **Conclusions.** In the end, we provided walkability scores with a more *scalable*, *explainable* and *readable* methodology which led to improve their *usefulness*.

1 INTRODUCTION

1.1 Context

We are experiencing an acceleration of global warming, the consequences of which are becoming life-threatening for a growing part of the world's population (GIEC, 2023). Therefore, there is a growing interest in rethinking our current car-oriented mobility in favor of active forms of mobility such as walking and cycling in order to meet Sustainable Development Goal 11 of the United Nations[1]. Active mobility also has great benefits for public health (Giles-Corti et al., 2016), the economy (Santos et al., 2023) and the general quality of life (Rosso et al., 2011).

We consider that the will to satisfy a need is the first determinant of the adoption of a mobility, and a necessary condition for the choice of pedestrian mobility is access to a suitable offer within a "walking distance".

Here, urbanism plays a key role in the distribution of modes of transportation for mobility with the idea that the "best mobility is no mobility", as expressed in concepts such as "15-minute cities" (Moreno et al., 2021), where everyone has access to services they need to live, within a 15-minute walk or bike ride from their home. Additional mobility is then used for leisure and not out of necessity.

1.2 Problematic

This "15-minute cities" concept hence relies on a diversity of amenities (places of employment, leisure, shopping…) accessible (in this article, we understand this term to mean "reachable") within a "walking distance" (a distance that people are willing to walk such as in (Yang and Diez-Roux, 2012)) which we therefore consider as the basis of a walkable environment.

The study of walkable environments is what drives our research. In the literature, works about walkability try mainly to find out where people would actually walk as exposed by the review (Hall and Ram, 2018). And if the latter answer a key question about the suitability of the urban environment for walking, the impact of their conclusions would benefit from a more **scalable**, **explainable** and **readable** methodology.

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[1] https://www.un.org/sustainabledevelopment/cities/ (accessed 11/2023)

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Elements for this improved methodology can be found in the field of research on "accessibility" to amenities. Some studies such as (Gastner and Newman, 2006) or (Xu et al., 2020), for example, attempt to optimize the positioning and quantity of amenities in a geographic area to suit as many people as possible, while other summarize the variety of services available to everyone in an "accessibility score" (Nicoletti et al., 2023).

Therefore, we are motivated to develop a tool to assess the efficiency of the urban layout in terms of the available amenities so as to promote pedestrian mobility. In this study, we will answer the following question: "How can we evaluate, at the level of a whole city and with street segments as spatial units, the degree of pedestrian accessibility achieved by the Points of Interest (POIs), according to the opportunities they offer and their location in the urban plan?".

1.3 Content of this Work

This work aims to revisit the foundations of walkability scores by focusing on the degree of accessibility offered by amenities, assuming that the decision to make a journey on foot begins with the ability to meet one's needs within a walkable distance.

Building on accessibility studies, we will reformulate the purpose of the *Walk Score* as "Pedestrian Level of Accessibility Score" and simplify the calculation by keeping only two parameters: the distance to the surrounding "amenities" and their relative "importance" within the mix of amenities. This second parameter, the "importance of an amenity", will benefit from a more general estimation method. Finally, we will categorize the trips to calculate a score per category of trips as a complement to a global walkability score.

2 STATE OF THE ART

2.1 Brief History of the Walk Score

(Hall and Ram, 2018) shows that the *Walk Score* is a reference tool to summarize the available amenities and city layout. From its original publication as the *Walkability Index*, what is now known as the *Walk Score* has evolved through various iterations, which we report on here.

2.1.1 Walkability Index

Among the tools to assess the walkability of cities, "Walkability Index" is a reference developed by (Frank et al., 2005). It is based on the recognized framework of the 5Ds (density, diversity, design, distance to transit and destination accessibility), which provides a methodology to assess the characteristics of a built environment that promote walking (Ewing and Cervero, 2010).

The index is calculated as a combination of four geographic variables: net residential density, intersection density, land use mix, and the ratio of retail space to floor area (as a later addition).

Each of the variables is weighted based on sociological and demographic studies. Originally developed to estimate where people actually walk, the system has since been widely used and studied (Hall and Ram, 2018).

2.1.2 Walk Score

This index was later transformed into a "Walk Score" used on a commercial website[2] with some variations to inform the public about the attractiveness of a neighborhood in terms of available amenities.

(Frank et al., 2021) reports some parts of the methodology used (some details are protected by copyright and are withheld from the public): the Walk Score is calculated by evaluating the straight-line distance from a starting point to the nearest destinations in nine different categories, including grocery stores, restaurants, general stores, coffee shops, banks, parks, schools, bookstores, and entertainment venues. For all categories except restaurants (where ten are considered), cafes (where two are considered) and stores (where five are considered), only the closest destination is considered. This adjustment takes into account the increased attractiveness of several nearby complementary amenities. The distances are then converted into amenity scores on a scale of 0-100 using a polynomial distance decay function. These amenity scores are weighted based on research findings and then aggregated to obtain the final walk score, which is also on a 0-100 scale. Finally, a 0-5% deduction is made that takes into account the average block length and intersection density within a 1.5 mile radius of the starting point.

2.1.3 Street Smart Walk Score

The methodology of the "Walk Score" was later revised into a "Street Smart Walk Score" by the original authors of the "Walkability Index" (Frank et al., 2021), whereby the Walk Score was assessed from an address primarily using distances based on the street

[2] https://www.walkscore.com/methodology.shtml (accessed 11/2023)

network and the function of decay with distance was adapted to different categories of amenity.

2.2 Other Works of Interest

2.2.1 Accessibility

Originally, (Hansen, 1959) defined accessibility as a distance-weighted property of a Point of Interest (POI). More generally, accessibility measures travel costs and the quality/quantity of opportunities, as shown in the review (Páez et al., 2012). Accessibility can therefore be measured from a population perspective (e.g. the availability of services) or from a destination perspective (e.g. the catchment area).

(Nicoletti et al., 2023) classifies Points of Interest into seven categories inspired by Maslow's hierarchy of needs (Maslow, 1943). Then, the closest point of interest in each category is considered to assess accessibility in each road segment. The final score is calculated as an aggregation of distances, with the importance of the categories being weighted by a panel of experts.

2.2.2 Studies Regarding Walkability Scores

(Zhao et al., 2021) shows that it is important to consider the pedestrian network instead of the road network in the analysis, especially for Asian cities. Regarding the incentive of amenities to walk, the article sorts the amenities into ten categories (an 11^{th} gives a "mixing index") and applies a decay by network-based distance but also by the number of amenity units to account for redundancy. In their work, the authors want to adapt the algorithm for densely populated Hong Kong.

(Gorrini et al., 2021) evaluates the degree of walkability based on four criteria: accessibility, comfort, safety and attractiveness, whose values are normalized, distributed in deciles and summarized in a final score.

(Lam et al., 2022) applies the Walk Score algorithm with the additional parameters of "greenery" and "proximity to public transport" to the entire Netherlands and compares the results with those of a national study on mobility, in which some correlations were found.

2.2.3 About a Walkable Distance

In studies of walkability, the question arises as to the distance that is to be considered "walkable" and can serve as a reference for the evaluation of a "degradation with increasing distance"' in the convenience of an amenity. (Yang and Diez-Roux, 2012) reports from a 2009 survey of 300,000 people in the USA who had walked a total of more than a million trips, that the mean and median distances *walking* were 0.7 and 0.5 miles (or 1.13 and 0.80 kilometers) respectively.

2.3 Comments

2.3.1 Purpose of the Index

As for the original purpose of the index, various efforts have been made to find a correlation between the calculated values and actual pedestrian activity on the streets, but as noted in the review (Hall and Ram, 2018), the scoring system is best suited to assess the quality of a built environment in terms of connectivity and the distribution of amenities. For example, the tool does not take into account the sociological and environmental factors that are part of the decision process to walk.

2.3.2 Choice of Parameters

We assume that the parameters "connectivity" and "block length" in the Walk Score formula are intended to capture psychological motivations and deterrents to walking caused by the urban environment, as described by (Lynch, 1960) in "The Image of the City".

Ultimately, however, these parameters appear to serve as a calibration of the formula to extrapolate the calculation of the score from a limited sample of surveyed people. As a result, the index/score loses in **scalability** as it relies on surveys with specific and limited spatial coverage, and furthermore it loses **explainability** as the formula becomes increasingly complex with parameters that are not so simple and meaningful. Furthermore, as already mentioned, the intended purpose of predicting walkability is not fully achieved.

This also applies to the idea of adjusting the decrease in importance of a POI with increasing distance by a formula adapted to different categories of facilities: to refine the index/score so that it matches the observed walks, it again loses **scalability** and **explainability**.

2.3.3 Importance of the Amenities

The Walk Score and other studies such as (Su et al., 2017) rely on surveys to assess the importance of amenities, which has several limitations, it is not exhaustive in terms of the variety of amenities, it requires some resources to conduct the survey at a sufficient scale and it does not necessarily translate well to other populations and locations (limitations in scalability mentioned earlier).

2.3.4 Exposing the Results

The various studies that use the Walk Score such as (Gorrini et al., 2021) and (Lam et al., 2022) or one of its variations, often end up with an index/score rendered on surfaces, while we want to evaluate the walkability of paths. With the move to network-based distances to amenities, it even seems like a missed opportunity to not render the scores directly on the paths. Finally, this reduces the **readability** of the index.

2.3.5 Accessibility

The works on accessibility mobilize intuitive and therefore more explainable methods. They must be tailored to the study of walkability and take into account the largest possible range of amenities that specifically induce pedestrian mobility. Estimation of the importance of amenities also exhibits significant variations between studies, usually with limited coverage on the diversity of amenities.

3 PROPOSED INDEX

3.1 Purpose of the Score

First, we propose clarifying the purpose of the index by pursuing the objective of evaluating "pedestrian accessibility", which reflects the efficiency of the urban layout. We do not intend to explain the observed walking behavior. From the point of view of the urban planner, the question answered by the scoring can be formulated as follows: "how well equipped is a particular street in terms of facilities within walking distance and their respective distance". From the citizens' point of view, it gives a "convenience of living somewhere" independently of an external means of transportation. The point here is to ask a more direct, easy-to-answer question. So we hope to gain in **explainability**. In the following, we will refer to our score as "pedestrian level of accessibility score" instead of "walkability score" to reflect this adaptation of purpose.
Our index is computed in respect of the following hypotheses:

- we consider statistically averaged persons in terms of physical abilities and needs
- all street segments are of the same perceived quality (street width, vegetation, etc.) and the altimetry is not considered
- all amenities in a category are of the same quality
- we consider mobilities at daytime on an averaged day

3.2 Simplification of the Score Calculation

Our walkability index has its roots in the approach used in accessibility studies such as those conducted by (Páez et al., 2012). To align with this approach, we simplify the calculation of the walkability score keeping only two parameters: a decay with increasing distance to amenities and their relative importance in the mix of amenities.

$$Score = \sum_{k=0}^{amenities} Decay(dist_k) \times Importance_k \quad (1)$$

This decay function is taken strictly linear (see the green line on figure 1) and not specific to a given category of amenity to gain in **explainability**. Additionally, in our study, the distance itself is evaluated using the network of streets as in the latest iteration from (Frank et al., 2021) which improves precision in comparison to using distances along straight lines.

$$Decay(dist) = 1.0 - \frac{dist}{walkable\_dist} \quad (2)$$

if $dist \leq walkable\_dist$, else $Decay(dist) = 0.0$

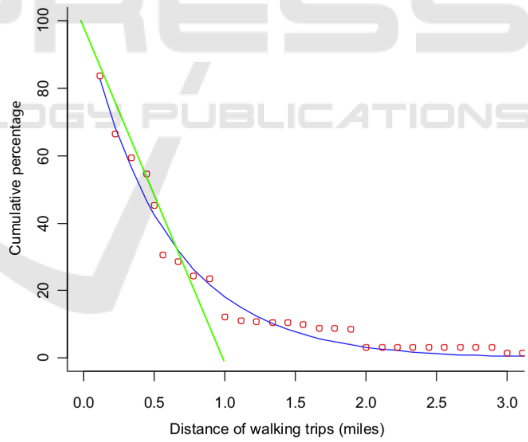

Figure 1: Cumulative percentages of walking trips by distance, red dots are from a survey, blue line is an interpolation and green line is our simplification as a linear regression which captures about 80% of the cumulative percentages of walking trips by distance (adapted from (Yang and Diez-Roux, 2012)).

3.3 New Method to Estimate the Parameter "Importance of an Amenity"

Every day, all the people in an area set out to satisfy their needs. Given a sufficiently large and contiguous geographic urban area, we can even approximately assume that all amenities satisfy all needs of the population (daily trips in and out of the area become anecdotal). We can therefore assume that an amenity satisfies the needs of the population on average up to its **daily attendance** (as a number of persons) and we propose to consider this as the importance of the amenity.

It should be noted that considering a large area also allows for statistical averaging and helps to eliminate a number of considerations relating to the inhabitants on the one hand (age, gender, socio-cultural background, individual sensitivities, skills. . .) and the amenities on the other hand (quality, individual economic issues, particular type of business. . .).

This method of evaluation has the advantage of being universal (all amenities are visited) and objective (it can be measured). We know that this data can be found (Google Maps offers hourly attendance as a tip, e.g. "more or less frequented than usual"). However, for our study we were unable to gather sufficient data, so we initially estimated this parameter of daily attendance using assumptions. In terms of a commercial application, there would be a simple method to accurately determine the importance of each POI without relying on a survey that is limited in its geographical coverage and in the variety of facilities considered.

3.4 Computation of Scores per Trip Category and Their Synthesis

To make our index more **useful**, we compute scores for different trip categories defined in the general survey on mobilities (INSEE, 2010) to which we can associate various amenities.
Trips categories and their related amenities:

- "groceries and shopping": shopping centers, malls, downtown shops. . .
- "work": places of employment
- "leisure": sport centers, restaurants, coffee shops, cultural places, entertainment venues. . .
- "studies": any educational establishment from elementary school to universities
- "administrative and healthcare": public administrations, hospitals. . .
- "visits": friends and parents to visit

Relying on open databases, we managed to gather a quite exhaustive list of the geolocalized amenities to represent the trip categories (see data sources in section 4.4.1). We interpreted the category "visits" as the potential for a social life proportional to the population localized at a walking distance (as we consider averaged persons in an averaged city). Looking for the number of inhabitants per street, we categorize the building footprints according to the land use (see figure 2) and associated a number of inhabitants to each: 3 for "habitations low density", and a value proportional to the building's height and its floor area for "habitations medium density" or "city center". In the end, we make the assumption that each building becomes an attractor in proportion to the number of inhabitants occupying it.

The scores per trip category are then combined by a weighted sum to a "global score" using each category's share in the repartition of trips (see table 1) as the weighting that we find in the aforementioned survey (INSEE, 2010).

$$Score = \sum_{k=0}^{categories} category\_score_k \times weight_k \tag{3}$$

3.5 Exposing the Results

In order to improve both **readability** and **explainability**, the not null scores computed for our large geographic area were divided into quintiles for each trip category (e.g. the 1/5 of the highest scores in trip category "work" on all road sections form the first quintile for this category). This distribution can then be used as a normalization for the scores in different geographical areas, allowing comparative analysis.

The resulting scores are rendered on the network of streets whose walkability is being estimated. This should improve **readability**.

It is also informative to display a score per category of trips as well as the combined score described in 3.4.

It should be noted that the color scale is adapted from the European energy label for household appliances, which is already familiar to the general public.

4 IMPLEMENTATION

4.1 Computational Methods

Inspired by methods from numerical simulations we turn the equation (1) used to evaluate the scores for a trip category, into the following computation:

$$S = A \times b \tag{4}$$

with A a square matrix of the decays in importance related to the distances from every streets segments to every streets segments, S the unknown scores and b the vector of the importance of the amenities for a trip category associated to their closest street segment. A is very sparse as decay is zero above the reference walkable distance between two street segments.

This way, the computational cost relies almost entirely on the construction of the matrix A and allows to evaluate the level of opportunity offered by almost any number of amenities to almost no further computational cost.

4.2 Algorithmic Translation of the Index

The main steps for the computation of the score are:

- conversion from a pedestrian network of streets describing the city to a topology of streets segments (list of neighbors)
- computation of the matrix A reporting the *decay with distance coefficients* using equation (2) and taking the network based distance between each pair of streets considered
- each amenity is classified in a trip category
- each amenity is given an importance (see 3.3)
- projection of the amenities onto the geometrically closest street segments (to construct vector b)
- computation of the product $S = A \times b$ (equation (4)) for each trip category
- normalization of the scores per quintiles against the scores at a metropolitan scale
- rendering of the score on the streets network for each trip category
- combination of the scores to get one final “pedestrian level of accessibility” score
- rendering of the final score on the streets network

4.3 Softwares Involved

The method has been implemented in Python code with GIS algorithms from GeoPandas (Jordahl et al., 2020). The construction of matrix A has been thoroughly optimized by leveraging SciPy’s (Virtanen et al., 2020) sparse matrices and NumPy’s (Harris et al., 2020) high-performance C-based operations.

The renders are performed with Folium (python-visualization, 2020).

4.4 Data Sources

4.4.1 Geographic Data

The street network used in the study (and curated to keep only the pedestrian network) originates from the IGN[3] (French National Institute of Geographic and Forest Information). The amenities are extracted from Open Street Map[4] for categories “groceries and shopping”, “leisure”, “studies”, “administrative/healthcare”, from the SIRENE database[5] for category “work” and from the IGN for category “visits”.

4.4.2 Sociologic Data

The sociologic elements from this study comes from the *INSEE*[6] (National Institute of Statistics and Economic Studies) which is a public institution attached to the French Minister of the Economy, Finance and Industrial and Digital Sovereignty. Its mission is to collect, analyze, and disseminate information about the French economy and society throughout its entire territory.

5 RESULTS

5.1 Description of the Case Study

We will first illustrate the proposed scoring system computing scores for the town of *Sautron*[7] (French city with 8,473 inhabitants in 2020) which has a relatively simple urban layout.

The city is organized around a central street, a small city center and some sports facilities on the western side. The town hall of Nantes is located to the southeast, about eleven kilometers away. Sautron is surrounded by an industrial area (to the east), a highway to the south and some vegetation (both agricultural and natural) to the north and west sides.

We will then apply our scoring on the vaster and more heterogeneous metropolitan area of *Nantes Métropole* (French city of Nantes with suburbs, 665,204 inhabitants in 2019[8]).

Nantes Métropole consists of a historic center located in the middle of a ring road (see figure 2). It is divided horizontally by the Loire River, which cuts out a large island below the city center. The area is divided into twenty-four municipalities, with Nantes being the most important.

[3] https://geoservices.ign.fr/bdtopo (edition 2023-06-15)
[4] http://download.openstreetmap.fr/ (accessed 11/2023)
[5] https://www.sirene.fr (accessed 11/2023)
[6] https://www.insee.fr (accessed 11/2023)
[7] https://fr.wikipedia.org/wiki/Sautron (accessed 11/2023)
[8] https://fr.wikipedia.org/wiki/Nantes_Metropole (accessed 11/2023)

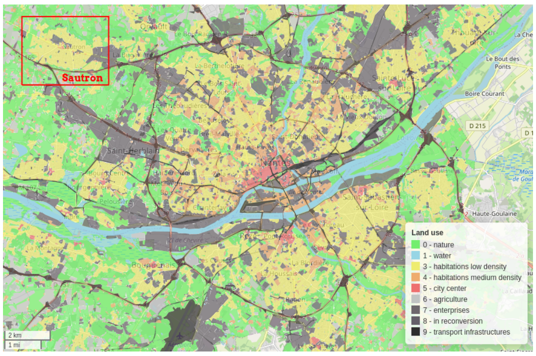

Figure 2: General map of Nantes Métropole and location of Sautron in the northwest.

We take *Nantes Métropole* as our "large area of reference".

The distribution of trips per purpose discussed in section 3.4 is taken from the generic survey on mobility (INSEE, 2010):

Table 1: Distribution of trips according to their purpose for *Nantes Métropole* (INSEE, 2010).

Purpose	Weekday	Saturday	Sunday
Groceries and shopping	20%	35%	10%
Work regular place	19%	4%	1%
Leisure	16%	24%	23%
Studies	12%	4%	0%
Visits	10%	17%	12%
Administrative and healthcare	6%	3%	4%
Other	17%	13%	50%

Then, the weight for trip purpose k and for an averaged day is:

$$w_k = \frac{5}{7} \times w_{weekday} + \frac{1}{7} \times (w_{saturday} + w_{sunday}) \quad (5)$$

These statistics are obtained with the following methodology:

- a trip is defined as a displacement from a destination to another, a new trip is registered each time a purpose is achieved
- return trips are not considered
- respondents are six years old and above

Regarding the reference walkable distance (see 2.2.3), for our investigation, we consider a value of 1.0 miles (1.6 kilometers) for the whole round trip according to the green line on the figure 1: at 400 meters the importance of an amenity is divided by two and at 800 meters (1600/2) it becomes null.

5.2 Results for Sautron

5.2.1 Scores per Trip Categories

We apply our algorithm to the city of Sautron and obtain the values for pedestrian accessibility scores showed in the figure 3.

(a) Work: we see that most of the work offers comes from the industrial zone on the east as well as the institutions of the city center and the shops on the main pathway

(b) Shopping / Groceries: most of the shopping offers is situated near the central road

(c) Leisure: there are many sports facilities and an entertainment venue at the west of the city center

(d) Health / Institutions: most of the institutions take place around the city hall at the city center

(e) Studies: the schools are mainly located at the city center in Sautron

(f) Visits: most of the population is concentrated around the central road and city center with the density getting lower further away

Satellite imagery as well as local cartography already provided this kind of information, so the added value here comes from the synthesis as well as the display of the geographic scope of the service provided by the amenities.

We also gain a comparison with *Nantes Métropole* against which the scores were normalized. In most categories, the scores experience a quick decay with the increasing distance as the amenities are in a low number and quite concentrated.

5.2.2 Global Score

We combine the scores from the different categories into one global "pedestrian level of accessibility score" using, as weights, the distribution of trips from (INSEE, 2010) described previously (see 5.1). We get figure 4.

For Sautron, as the best score "A" is essentially absent, we can say that its city center is not as well provided with amenities as the center of *Nantes Métropole* and that's why the city benefits from good public transportation to the latter. People living in streets ranking "C" can carry out some activities on foot but will probably appreciate using a bicycle to gain better access to the whole mix of Sautron's amenities. In comparison, the population on the streets ranking "D" and "E" have an increased dependency on motorized vehicles (which will be confirmed analyzing *Nantes Métropole* in the next paragraph, these two scores being quite bad).

5.3 Results for Nantes Métropole

Nantes Métropole is a more heterogeneous territory than Sautron, composed of a variety of urban environments ranging from a dense historic center to small communities and interurban places. Nature, with its

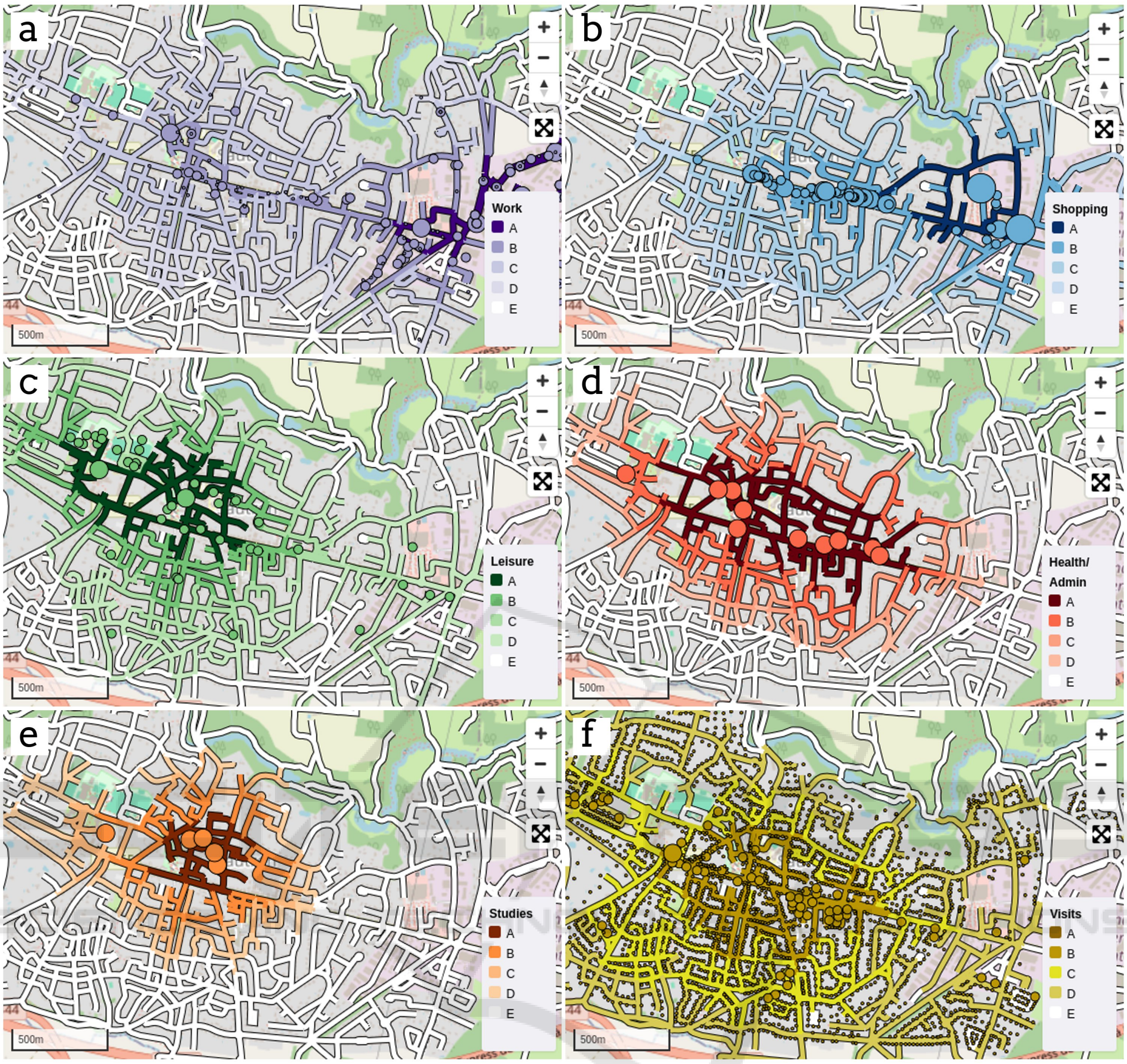

Figure 3: Scores and amenities (size related to importance) associated to work (a), shopping (b), leisure (c), health/administration (d), studies (e) and visits (f) normalized over the results on Nantes Métropole.

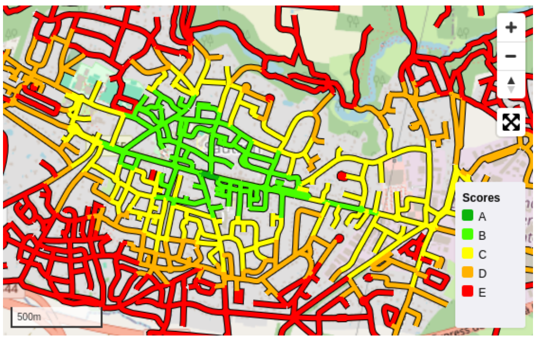

Figure 4: Global pedestrian level of accessibility score for Sautron.

parks and rivers, and industrial areas also characterize the area.

We evaluate the scores from the different categories of amenities as well as the overall rating on *Nantes Métropole*. For the sake of brevity, we only report on the latter here (see figure 5).

Rank A: the city center (1) unsurprisingly yields excellent scores ranking A in every trip categories with amenities in over abundance to serve also the neighboring districts and municipalities. With (2), (3) and (4) we identify secondary centers, and most notably their geographic extent, which are also well equipped with amenities in all categories. Also, (4) encompasses the biggest building of *Nantes Métropole* (*Sillon de Bretagne*, about 2,500 inhabitants) which is located close to an industrial busy road/area with jobs and shopping offerings. It should be noted that the

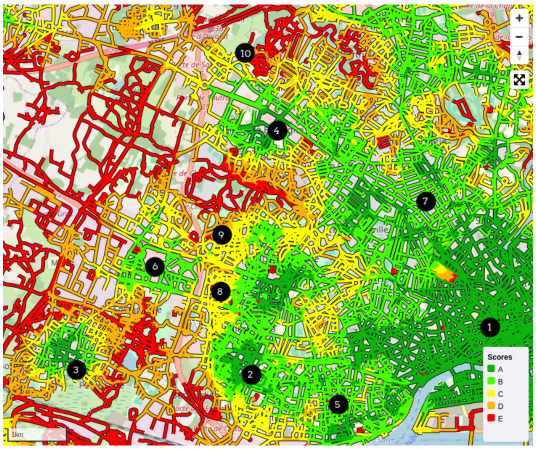

Figure 5: Zoom on the scores on the western districts of Nantes Métropole obtained for a round trip walkable distance of 1.6 kilometers.

good ranking fails to report that the area is quite unpleasant to reach on foot, as it is mainly designed for car-oriented mobility.

Rank B: (5) has slightly fewer offers in shopping and employment than the city centers, (6) is an industrial area that is hardly inhabited but offers employments and shopping opportunities for people willing to come with motorized means of transport. Last with this rank, (7) only maintains a good score due to its proximity to two large and well-provided avenues.

Rank C: (8) is a residential area which gets a good employment rating from the industrial zone nearby, however it quite fails to answer the needs of its inhabitants in all the other categories. A good opening towards the better equipped east prevents it from getting a worse notation.

Rank D: as with (8), the place (9) lacks service in most amenity categories and is further convoluted, reducing access to better equipped places.

Rank E: (10) offers a place with poor access to any amenities and additionally with rather convoluted access. Its inhabitants are probably quite dependent on cars for their mobility.

5.4 Sensitivity Analysis of the Decay Function

The decay function described in section 3.2, reports on the decrease in opportunities offered by an amenity as the distance to it increases.

It depends on a walkable distance (see 2.2.3) that we chose at 1.6 kilometers (total round trip) for our case study (see 5.1). In order to characterize the sensitivity of this walkable distance, we compute our scoring with a value decreased by 50% to 0.8 kilometers and increased by 100% to 3.2 kilometers.

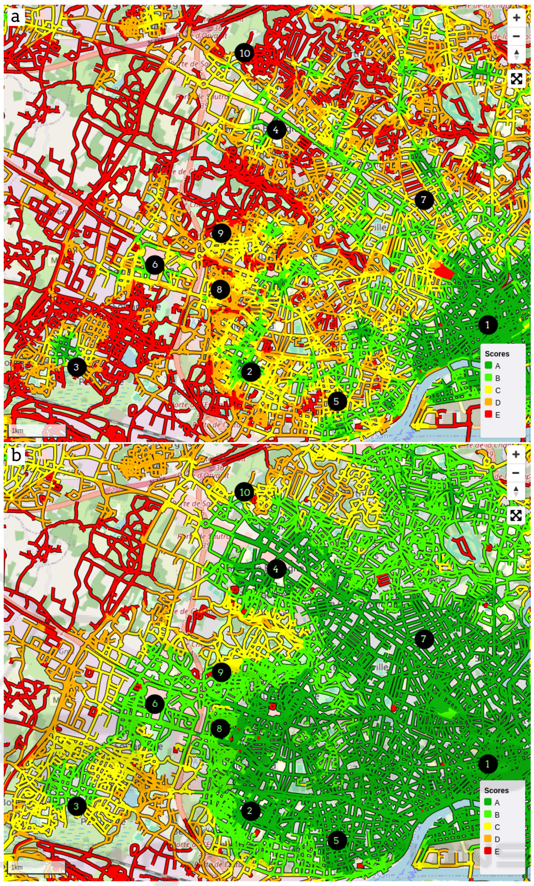

Figure 6: Zoom on the scores on the western districts of Nantes Métropole obtained for a round trip walkable distance of 0.8 kilometers (a) and 3.2 kilometers (b).

The result for the western districts of Nantes Métropole is exposed on figure 6 to be compared with figure 5.

Regarding the decreased walkable distance (figure 6.a) we observe that only the places well furnished with amenities keep a good score, while those that mainly benefited by well provided nearby places get well degraded scores. As such, the residential only districts (7), (8) and (9) have their scores devalued, while well-provided environments get some credits. Indeed, with this analyze, the local environment gains a greater importance and we can say that this choice of walkable distance would better reflect the mobility of senior people who are known to walk smaller distances.

About the increased walkable distance (figure 6.b) most of the places considered get an improved score compared with round trip walkable distance of 1.6 kilometers as they benefit from the proximity with the

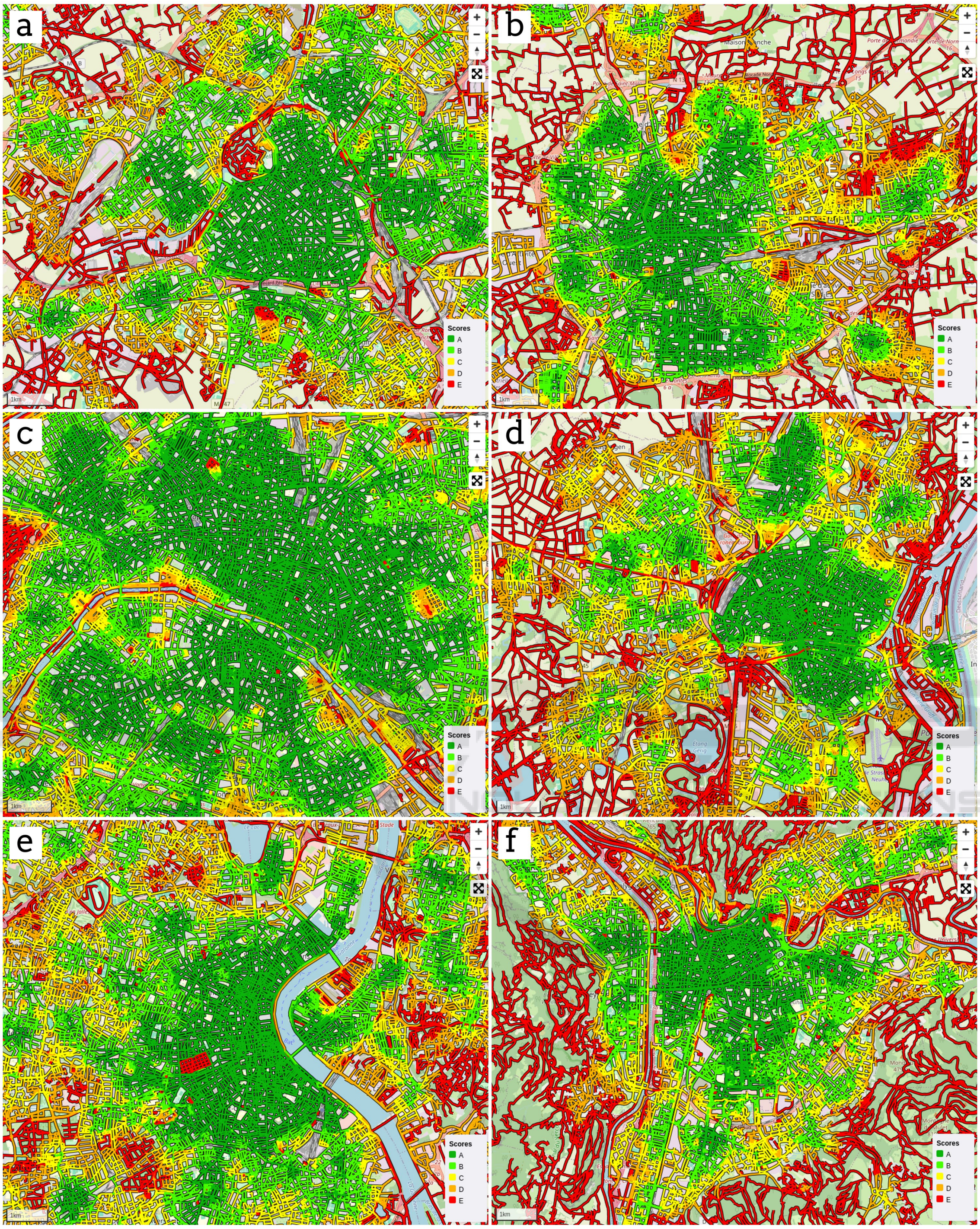

Figure 7: Scores on various French cities: Lille (a), Rennes (b), Paris (c), Strasbourg (d), Bordeaux (e) and Grenoble (f).

center of *Nantes Métropole*. However, some places, such as ③ get a degraded score. This is because the normalization process described in section 3.5 leads to an equal number of streets (with not null scores) in each rank for the whole *Nantes Métropole*.

5.5 Scalability

To demonstrate good scalability of the method, we compute the scores for six other French metropolitan areas on the figure 7.

In this figure, the distribution of scores into quintiles is done independently for each city, which prevents the comparison of absolute scores. However, we could select one city against which the others are normalized to allow such a comparison.

A similar figure could be generated to display the scores for each category with the associated amenities. Also, we provide the map to the general public through a website [9].

6 DISCUSSION AND CONCLUSION

In our study dedicated to walkability scores, we defined a more direct and easy-to-answer question than the usual literature (Hall and Ram, 2018) to gain in **explainability**. With the same prospect, we also chose to consider statistically averaged persons in an averaged city built of averaged streets and amenities. Revisiting these hypotheses make for as many opportunities of future studies. Again for **explainability**, we simplified the score calculation taking inspiration from works on accessibility to amenities. Also, for *scalability*, we revised the method to estimate the parameter "importance of an amenity" to a more universal and objective approach distinct from the approaches in the literature which are mainly based on surveys (Su et al., 2017). The surveys have the advantage of being quite precise in their conclusions but they are also quite limited in their geographic coverage and in the diversity of amenities considered. Unfortunately, with our limited time and resources, we ended up estimating the parameter with assumptions, however as mentioned, the data exists and it should be possible to acquire it for a commercial application. The statistical and geographic data for our case study otherwise come from very generic sources which should allow to easily apply the scoring to at least the whole French territory. We evaluated scores for different trip categories (for *usefulness*) and performed their combination into a final score. The rendering of the computed scores was also worked out for *readability* which offers finer details compared to scores aggregated on surfaces in (Gorrini et al., 2021) or (Lam et al., 2022). In the end, we discussed here only one aspect of the question "where do people actually walk" behind walkability scores. Our purpose was indeed to lay a more robust foundation to those scores, considering that the accessibility to amenities is the starting point of any mobility.

Additionally, for future developments, we are going to interview urban planners so as to refine the usefulness of our scoring and help them make more informed decisions.

[9]https://villes-marchables.huma-num.fr

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