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Territorial Infrastructure: Drafting of a Calculation Evaluation Method

By Elsa Negas[*] & Rui Seco[±]

This study proposes a method for calculating the level of urban infrastructure and basic urban services on a given territory. It aims to contribute to a more accurate knowledge of the territory and the city, through the creation of an assessment tool for the urban condition, with the goal of overcoming imprecision hindering urban planning and management. Urban infrastructure is here understood in a broad sense, integrating usual urban attributes —roads, pavements, electricity, water supply, sanitation, etc.—but also a set of urban services and equipment traditionally provided by city and urban environment—administration, representation, culture, health, education and security, among others—and also other conditions diagnosed as significant for the current evolutionary trend of extended urbanity, such as mobility—integrating roadways, public transport networks, soft mobility devices and infrastructures —and access to and integration in communication and information networks —voice and data communication, fix and mobile. The development of this calculation method takes into account different relative weights for this set of conditions in order to obtain a balanced assessment of the level of infrastructure. In the future, the next stage will consist of testing in the field in order to fine tune and validate its usability in different scenarios.

Keywords: *urban condition, territory, infrastructure, measuring systems, calculation*

Introduction

This study proposes a method for calculating the level of urban infrastructure and basic urban services, addressing the inaccuracy in this field by providing a new tool to measure and compare these assets on a given territory.

Authors like Nijhuis and Jauslin (2015) state that planning and design of cities and regions are important issues to address sustainability and face the "climate crisis puzzle"[1]. This is particularly significant facing the global urbanization processes of today's networked metropolis, where cities are shaped and interconnected by infrastructure through the territory, a process towards what

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[1]"Cities and regions are believed to be a significant part of the 'climate crisis puzzle' and their significant contribution needs to be assessed if we are to address the various environmental and social challenges to achieve sustainability and resilience on a large scale. For this to be materialized, though, design principles need to take part in the territorial transformation processes" (Nijhuis and Jauslin 2015).

François Ascher called "metapolis"[2]. These evolutions tend to replace the role of traditional cities, in the sense described by city historians like Lewis Mumford (Mumford 1938), changes that Françoise Choay - one of the major references in architecture theory in the 20th Century - called "the reign of the urban and the death of the city" (Choay 1999). In an effort to better understand and interpret these complex and intertwined transformations, recent theory is already referring to the present as an "infrastructure time" (Addie 2022)[3].

The calculation of the level of territorial infrastructure aims at contributing to a more accurate knowledge on the territory and the city, in order to overcome the inaccuracy and ambiguity that Bourdin (2010), among others, states that hinders planning, reasoning and regular urban management[4]. Angheloiu and Tennant (2020) emphasise that cities and regions "need to concentrate their focus on achieving the goals of global policy frameworks in response to the climate crisis while they focus on a response to zero-emissions, net zero routes and zero-waste solutions". Different fields of knowledge, from climatology to health or social responsibility, have already created indicators that measure complex situations, comprising multiple factors with variable relative weights[5].

Many features contribute today to the definition of the urban condition, which merges with social and economic dynamics. Recent swift evolutions in technologies and communications reorganized the production processes and services, having major impacts on the current transformations of the territory. This has affected traditional city cores which have lost their central importance and their role in economic and administrative functions has spread widely across entire regions, following new patterns of spatial organization and interconnection. Individual and public accessibility, road networks, information technologies and basic urban services—besides traditional urban infrastructures—are today key in defining urbanity, being difficult to quantify in an objective and precise basis. This study thus proposes the drafting of a tool for evaluating the features that are significant to establish an urban condition[6].

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[2]The *metapolization* described by Ascher (2001) is a continuous ongoing process with global impact that is reshaping the territory, in which connections through infrastructure, namely communications and technology, acquire major relevance (Ascher 2001).

[3]Addie (2022) has used the "infrastructure time" concept in order to analyze the production of infrastructure and to question several aspects of the production of urbanization and the urban condition (Addie 2022).

[4]Bourdin, in his highly influential text *L'Urbanisme d'Aprés Crise*, indicates the "triumph of vague concepts" and specifically in relation to the urbanism of the last decades, points out the "weakening of the scientific references and the multiplication of actors involved in decision and activity", aiming at a more accurate and reliable understanding of the urban environment (Bourdin 2010).

[5]Among multiple examples of this type of studies can be named Turker (2009) in the field of social responsibility, Greer and Watson (1987) in human health or Wofsy (2011) in climatology.

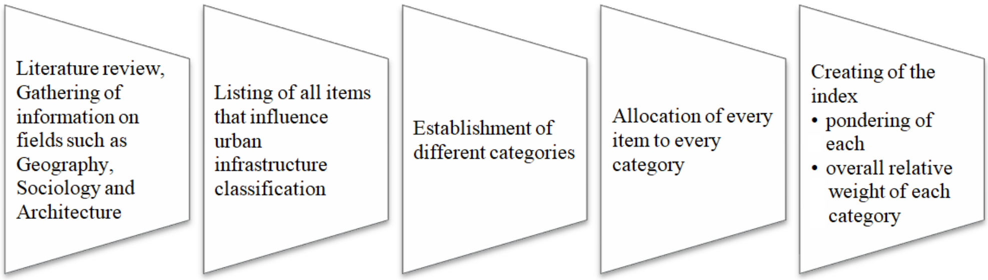
[6]Urban infrastructures open manifold political horizons, but realizing progressive infrastructure futures "require[s] a deep understanding of existing infrastructure institutional practices and how they are embedded in the preferences and aspirations of urban residents" (Simone and Pieterse 2017).

The objective is to create a pondered rating for the infrastructure level of a place, corresponding to a specific location. The classification can be made in any place in the world since the criteria considered are those commonly classified as urban infrastructure.

Methodology

With the purpose of creating a tool for the assessment of the infrastructure level, five stages have been outlined, conducting to the creation of a single calculation formula (Figure 1).

Figure 1. *Overview of the Process of Developing an Urban Condition Evaluation Tool*



Source: Elsa Negas & Rui Seco 2021.

The first step was a literature review on the urban condition and the most relevant infrastructure assets and basic urban services involved in its definition. This information supported the listing of a set of relevant items that make up the conditions and influence urban life, in a broad range that includes different sorts of services and facilities.

These outputs were then organized into specific different categories to make its processing operable and practical. The items were allocated to their categories, then the way to quantify their quality and availability was defined (in a specific-guided approach to every item), and their relative weights were pondered in the calculation of the categories. The overall relative weight of each category was also pondered, in order to balance its impact in the global formula.

This process is not yet finished or closed, as this balance is in the process of fine-tuning by experimenting its testing in the field, using the assessment formula in various conditions and different areas of the territory to make adjustments.

Implementation

For the purpose of creating an infrastructure evaluation method, urban infrastructure is considered in a broad sense, which integrates usual urban attributes —roads, pavements, electricity, water supply, sanitation, etc. —but also a set of urban services and equipment traditionally provided by the city and the urban environment —administration, representation, culture, health, education and security, among others —and also other conditions diagnosed by a bibliographic review as significant for the current evolutionary trend of extended urbanity, such as mobility —integrating roadways, public transport networks, and also soft mobility devices and infrastructures —and access to and integration in communication and information networks - voice and data communication, fix and mobile.

In the development of this method for the calculation of urban infrastructure and basic urban services are taken into account different weights of each of this set of conditions in order to obtain a balanced assessment. This balance will be fine-tuned through a process of testing in the field using the calculation in different conditions and areas of the territory. However, it must be noted that the relative weight of the distinct components of the formula should in the future be variable according to the purpose of its use, i.e., distinct variants of calculus may be produced in order to assess different aspects of the urban condition —to settle a business, the most important issues to evaluate are not the same of those to verify the urbanity of a residential neighborhood or the urban integration of a university campus.

On the other hand, the use of specific versions of this tool to systematically assess a given area of the territory will enable the opportunity to compare, identifying disparities and relative advantages, and to evaluate progress over time, creating new and reliable data that can be used to support urban management, decision-making processes and spatial planning.

This paper presents the design of the index, integrating all items identified as having influence in the infrastructure of the territory, grouped into categories with different relative weights. This composed index allows the calculation of the level of infrastructure and basic urban services in a spotted location[7].

Territorial Infrastructure Evaluation

The availability of infrastructure is not uniform throughout the territory. Yet, it is of the utmost significance at the present time, given our way of life increasingly based on technology, accessibility and communication. Both classical and technologically advanced infrastructures, as well as basic urban services, are indispensable for communities, inhabitants and their economic development.

The creation of a comprehensive calculation method for the level of infrastructures covers these factors, based on a field analysis to be performed for the assessment. This evaluation is based on the verification of the availability of a series of items of a specific location of the territory, both infrastructure and basic

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[7]Despite the limitations that an index may present, there are many advantages in synthesizing data, in terms of the simplicity when communicating information; the Portuguese Governmental Agency for the Environment recommends that indexes are designed to simplify data on complex phenomena in order to improve its reporting, gaining in intelligibility, clarity and usability of the collected information, while losing in detail and specificity (DGA-DSIA 2000). In this specific case, it has allowed the identification and classification of the items that influence infrastructure, as well as their quantification, facilitating its consulting, cross-referencing and use in future research.

urban services related. For this geographic point is then calculated a global value of urban infrastructure, using an equation that takes into account the different relative weight of a set of parameters.

The repetition of this process of identification and calculus for several locations throughout a given area will display the variations that occur in that territory.

To evaluate the degree of infrastructure five key infrastructure categories have been identified:

- transport systems (subway, train, bus, 'soft' mobility);
- basic urban services (administration, commerce, culture, health, education);
- 'traditional' urban infrastructures (streets, sidewalks, water supply and sanitation, energy/electricity, public lighting);
- automotive accessibility (roads, traffic, parking);
- telecommunications (voice and data networks, broadcasting).

These key infrastructure classes are given specific ponderings in the calculation, being themselves composed by several items. The weight of each specific category in the global calculation reflects its relative weight in the evaluation; this will eventually be adjusted to correspond to particular applications or requirements.

Drafting of the Calculation Method

For calculating the level of urban infrastructure, each class is assigned an elemental factor, integrating with different pondering the items that composes it on a scale of 1 to 5 ($I_i, i=1,2,\ldots,5$). The Infrastructure Index (*Inf*) is then calculated on the basis of the indicators per category in a weighted manner, as shown in the formula:

$$\begin{cases} Inf = \sum_{i=1}^{5} f_i I_i \\ \sum_{i=1}^{5} f_i = 1 \end{cases}$$

Notice that the weighting of each category conveys the relative weight it has in the infrastructure assessment.

The following five sections of the text present the construction of the calculation method for each of the identified five key categories, integrating their respective components and relative weights.[8]

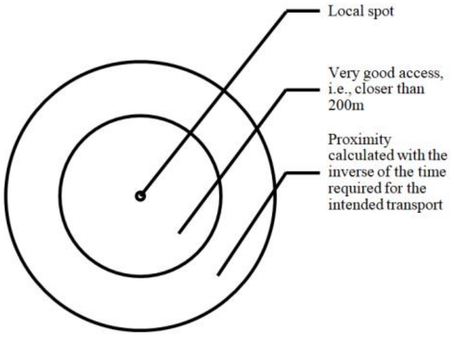
[8]The first two sections - transport systems and basic urban services - have been previously addressed by Negas and Seco (2020).

Transport Systems

For transport classification, the following factors are considered prevalent: proximity of access, frequency of passage and existence of a network of at least two distinct means of transport[9].

As the notion of proximity and accessibility is subjective, it was made uniform as follows: in the infrastructure index, the distance is calculated based on the duration of a walk, considering that 5km are travelled in one hour[10]. All accesses at a distance of 200m or less are considered to be very good, corresponding to a 2.4 minute walk[11] (Figure 2).

Figure 2. *Proximity to Transport*



Source: Elsa Negas & Rui Seco 2021.

The quantification of the frequency of each means of transport is based on a Likert scale with 7 levels[12], reflecting the time interval between consecutive public transports on working days in the 7h00-22h00 schedule:

7 - The time interval between consecutive journeys is a maximum of 3 minutes.
6 - A maximum of 10 minutes between consecutive carriage runs.
5 - The time interval between consecutive carriage runs is a maximum of 20 minutes.
4 - The time interval between consecutive carriage runs is a maximum of 30 minutes.
3 - The time interval between consecutive carriage runs is a maximum of 50 minutes.
2 - The time interval between consecutive journeys is a maximum of 2 hours.
1 - Otherwise.

This is intended to distinguish the frequency with which the location is served by public transport, either the nearest or the second alternative. To this classification is added the fact of whether or not night public transport exists (whatever the frequency).

[9]For information on mobility, public transport, and the quantification of its gaps, see Silva (2017) or Currie (2010), among others.
[10]Despite this subjectivity, the accessibility to transports and mobility are serious factors in establishing social exclusion, which needs to be addressed (Preston and Rajé 2007).
[11]On this matter, Carr et al. (2010), among others, have developed studies on walkability for pedestrians.
[12]The use in statistics of this type of scales has been further explored by Negas (2021).

Network transport indicates that the location under consideration is both a point of departure and point of arrival to a variety of other destinations and may have access to different locations. The branch transport designation means that the location has available a public transport which originates and terminates at a location where network transport then exists. The category 1 infrastructure index is calculated using the formula:

$$I_1 = \sum_{i=1}^{5}\left(p_i \times \frac{1}{t_i}\right) + p_6\left(0{,}5 \times \frac{n_i - 1}{6} + 0{,}5 \times \frac{n_i - 1}{6}\right) + p_7$$

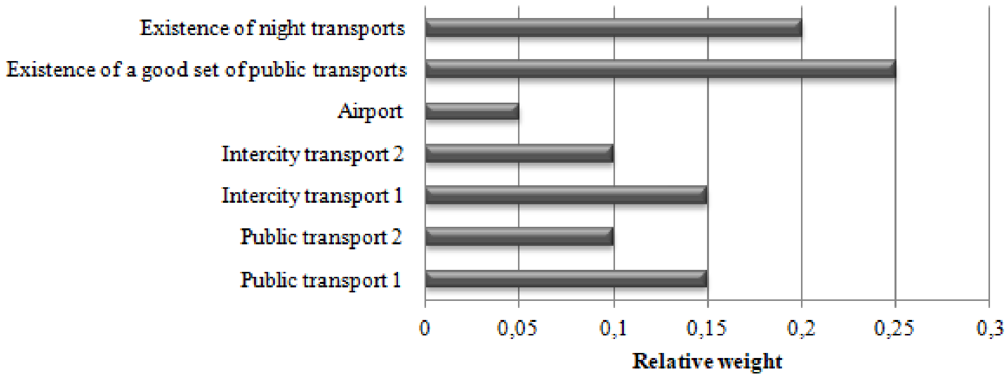
Subtitle:

I_1- value of the first index representing in the study the transport network, for the calculation of the infrastructure index (*Inf*)
p_i - relative weight attributed to factor i
t_i - travel time to factor i (accesses at a distance up to 200m are considered very good, valued as 1)

Items: i=1 nearest public transport; i=2 second nearest public transport alternative (for example bus and metro); i=3 nearest intercity transport; i=4 second nearest intercity transport alternative (it has to be different from the first one for example bus and train); i=5 airport; i=6 existence of a good set of public transports; i=7 existence of night transports.

After performing some simulations, the following weightings were established (Figure 3).

Figure 3. *Transport Systems Category Items Relative Weight*



Source: Elsa Negas & Rui Seco 2021.

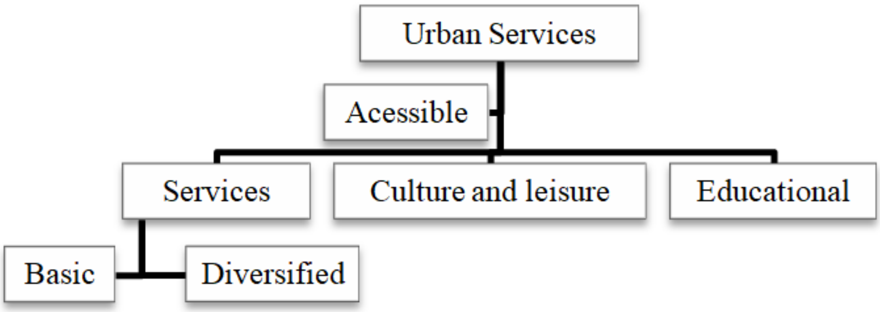
The sum of all weightings equals the unit:

$$\sum_{i=1}^{7} p_i = 1$$

Basic Urban Services

Infrastructure influences and is influenced by the existence of services, culture and leisure, as well as the existence of educational institutions (at different levels) and tertiary services (in this case different levels are also identified). In this criterion, the distance from where services are located is relevant and should be discriminatory. In this sense, all services that are more than two and a half kilometers away (corresponding to a 30 minute walk, as previously considered) should be classified as absent. Hence, proximity and accessibility are valorized in this criterion. The elements considered fundamental in urban services are presented in Figure 4.

Figure 4. *Different Urban Services*



Source: Elsa Negas & Rui Seco 2021.

In the second category, Basic Urban Services, the following items were considered of relevance:

- Tax Office.
- Post Office.
- Banking Services.
- Cinema.
- Theatre.
- Congress Center.
- Exhibition Centre.
- Tertiary sector levels I, II, III and IV.
- Schools levels I, II, III and IV.
- Higher Education.

Among these ten items, two are rated according to a 4 level Likert scale:

1 - Tertiary Sector:

Level I - coffee shop and grocery store.
Level II - ATM, pharmacy, clothing store, hairdresser.
Level III - diversified services, including insurance brokerage, telecom operators.
Level IV - verifies the previous level and accumulates large diversified commerce.

2 - Schools

Level I - elementary school.

Level II - elementary school (with either kindergarten and elementary school or elementary and II grade).

Level III – all schools up to highschool (at least one school of each level, from nursery).

Level IV - verifies the previous level and accumulates technical education.

The category 2 infrastructure index is calculated using the formula:

$$I_2 = \sum_{i=1}^{7}\left(p_i \times \frac{1}{t_i}\right) + \sum_{i=8}^{9}\left(p_i \times \frac{n_i - 1}{3}\right) + p_{10} \times \frac{1}{t_{10}}$$

Subtitle:

I_2 - value of the second index representing in the study urban services, for the calculation of the infrastructure index (*Inf*)

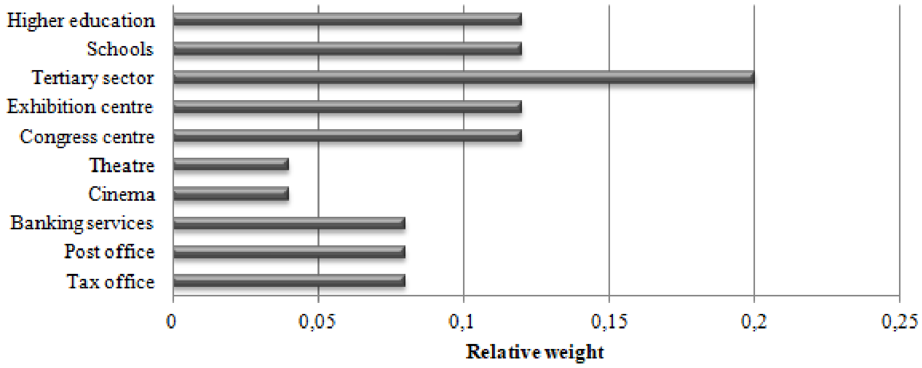
p_i - relative weight attributed to factor i if it exists within a radius of two and a half kilometers (corresponding to a 30 minute walk, as previously considered)

t_i - travel time to factor i

Items: i=1 tax office; i=2 post office; i=3 banking services; i=4 cinema; i=5 theatre; i=6 congress centre; i=7 exhibition centre; i=8 tertiary sector; i=9 schools; i=10 higher education.

After performing some simulations, the following weightings were established (Figure 5).

Figure 5. *Basic Urban Services Category Items Relative Weight*



Source: Estejo 2021.

The sum of all weightings equals the unit:

$$\sum_{i=1}^{10} p_i = 1$$

Urban Infrastructure

Regarding the category that classifies the existing urban infrastructure in a given location, the following analyses were considered:

- Existence or inexistence of infrastructure; if existent, its updating and modernity.
- Its quality, durability and suitability for the environment.

The following items were considered important:

Water supply;	Solid Waste Collection;	Sidewalks;
Sanitation;	Free collection of large waste items/ junk;	Handicap accessibility;
Street lighting;	Recycle bins;	Soft mobility lanes;
Electricity;		Urban equipment (benches, etc.).

The measurement in this index should enhance:

- The existence of infrastructure.
- The quality of the infrastructure.
- Their design and usability.
- The suitability of the employed materials.
- The most ecological and environmentally friendly options.

Accessibility is still an important point, and in this criterion a radius has to be defined, indicating the distance at which the infrastructures are considered to exist or not. The same 200m radius was considered (as already applied); in the case of infrastructure inexistence the index value has to suffer a penalty[13].

How to rank quality? The 3 most convenient modes are identified in this case study (more efficient, more durable and with better environmental performance); 4 different gradations can be assumed; Q_i, $i= 1,2,3,4$:

1 - None of the identified modes is being applied.
2 - The third mode is being applied.
3 - The second mode is being applied.
4 - The best mode is being applied.

On the items plumbing, sewerage, street lighting and electricity the quality has to be assessed.

In quantifying the infrastructure index, both the quality criterion [how collection is carried out and the frequency] and the separation of solid waste between differentiated or non-differentiated waste and recyclable or non-recyclable waste must be applied; this separation reveals population behaviour and

[13]In the case of recycling, the established maximum distance for considering eco-points existence is 400m.

accessibility, which in the case of recycling eco-points is considered to exist if the distance is less than or equal to 400m.

The item "free collection of large waste by public services" is a binary variable and assumes the value "1" when it exists and "0" otherwise.

The item sidewalks should classify their adequacy for circulation, mainly if they are elevated enough in relation to the road to avoid accidents and contact with gutters; the classification is made using a 4 level Likert scale:

1 - No sidewalks.
2 - There is a space for pedestrian circulation but at the same level as the road.
3 - There are elevated sidewalks, but do not permit handicap circulation.
4 - Everyone can circulate safely.

Handicap circulation requires wider sidewalks, access ramps and the non-existence of improperly parked cars; also in this item the classification will be carried out through a 4 level Likert scale:

1 - Does not apply.
2 - Applies with many limitations.
3 - Applies.
4 - All restrictions have been taken into account allowing good circulation for all.

The last item of the urban infrastructures category, soft mobility infrastructure, has undergone a strong implementation in various parts of Portugal, such as the entire district of Lisbon, with the implementation of proper tracks for the circulation of scooters and bicycles, and renting and sharing systems. These solutions are simultaneously more ecological, safer and allow people to move around in a way that is beneficial to the environment and health. Its classification will be carried out by a discrete quantitative variable with domain {1, ..., 4} corresponding to the following grading:

1 - No access to dedicated lanes within a distance of 12 minutes (one kilometer).
2 - With access to dedicated lanes within a distance between 6 minutes (half kilometer) and 12 minutes (one kilometer).
3 - With access to dedicated lanes within a distance between 200 meters and half a kilometer (six minutes).
4 - Dedicated lanes within a distance less than or equal to 200 meters.

As a result of strong innovations, both at the level of construction materials and their maintenance, the index for this criterion —urban infrastructure —should reflect and aggravate a penalization for the use of very polluting materials or of those that require inefficient maintenance. Thus in this criterion, whenever a non-polluting solution exists it should be considered as the most efficient option.

The infrastructure index for category 3 is calculated using the formula:

$$I_3 = \sum_{i=1}^{6}\left(p_i \times \frac{Q_i - 1}{3}\right) + p_7 \times b_7 + \sum_{i=8}^{10}\left(p_i \times \frac{n_i - 1}{3}\right)$$

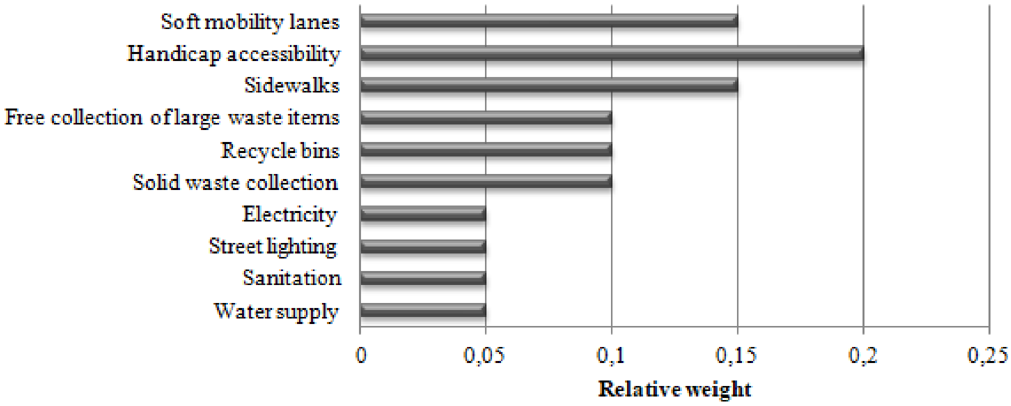
Subtitle:

I_3 - value of the third index representing in the study urban infrastructure, for the calculation of the infrastructure index (*Inf*)

Items: i=1 water supply; i=2 sanitation; i=3 street lighting; i=4 electricity; i=5 solid waste collection; i=6 recycle bins; i=7 free collection of large waste items; i=8 sidewalks; i=9 handicap accessibility; i=10 soft mobility lanes.

After performing some simulations, the following weightings were established (Figure 6).

Figure 6. *Urban Services Relative Weight*



Source: Elsa Negas & Rui Seco 2021.

The sum of all weightings equals the unit:

$$\sum_{i=1}^{10} p_i = 1$$

Automotive Accessibility

The level of infrastructure is also determined by the quality of the roads, the proximity to highways, i.e. ease of circulation, accessibility, parking and safety. Facility of circulation has to be rated taking into consideration the quality of road connections and safety. In this fourth category, Automotive Accessibility, the following items were considered significant:

- Quality of the roads.
- Proximity to motorways or expressways.
- Parking.

The index should value:

- Safety in the circulation both of cars and pedestrians.
- Ease of parking.

The item road quality is assessed on the ground without any distance being attributed. As in the previous case, the quality is classified on a 4 level Likert scale $Q_{i,}\mathrm{i} = 1, 2, 3, 4,$ which in this case combines the quality of the road surface with driving safety and the existence of a verge (or sidewalk) that minimizes the possibility of accidents:

1 - The track has no quality pavement or safety.
2 - The track has some quality in pavement and safety.
3 - The track has good quality but safety can be improved.
4 - The track and safety are of the desired quality.

The proximity to motorways or expressways allows easy access to other locations, which can be important in terms of employment or supply. This classification will be made on a Likert scale with 7 levels (1- very far and 7- very close), which must be analyzed on a case by case basis. Parking availability will be rated on a Likert scale where:

1 - Safe parking is not available.
2 - Parking is scarce or difficult to access.
3 - Parking is sparse but secure and easily accessible.
4 - Easy to park and safe.

The category 4 infrastructure index is calculated using the formula:

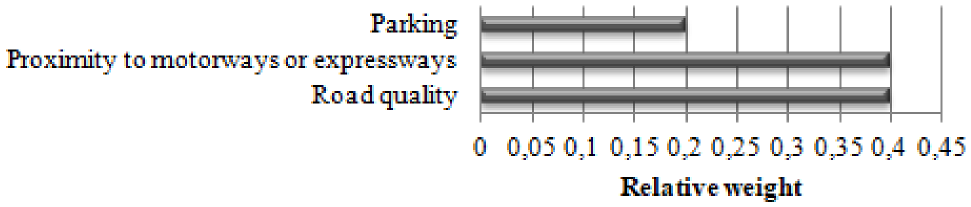
$$I_4 = p_1 \times \frac{Q_1 - 1}{3} + p_2 \times \frac{Q_2 - 1}{6} + p_3 \times \frac{n_3 - 1}{3}$$

Subtitle:

I_4 - value of the fourth index representing in the study road accessibility, for the calculation of the infrastructure index (*Inf*)

Items: i=1 road quality; i=2 proximity to motorways or expressways; i=3 parking (Figure 7).

Figure 7. *Automotive Accessibility Items Relative Weight*



Source: Elsa Negas & Rui Seco RS 2021.

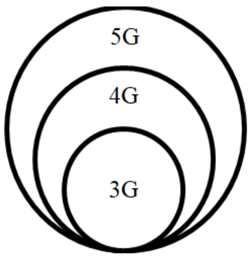
Telecommunications

In this category the following factors were valued:

- Type of internet connection.
- Availability of fix and mobile data connection.
- Number of available connection providers.

In the Portuguese situation, the availability of connection on a specific location can be consulted on-line[14]. It is a fact that some areas only have the possibility of ADSL communications, while others already have the possibility of fiber optics connection; the infrastructure index must highlight this difference in a reinforced way. In the scope of fiber optics, 5G already exists in parts of the country and the possibilities are shown in Figure 8.

Figure 8. *Fiber Optics Modalities*



Source: Estejo 2021.

In this telecom specification the following issues were considered important:

- Number of providers.
- ADSL/Fiber optic.
- Meagre internet access.

It should be noted that a binary variable has been created:

[14]The availability of internet and mobile connection in the Portuguese territory can be consulted on: https://pplware.sapo.pt/informacao/anacom-freguesias-internet/.

$$b_1 = \begin{cases} 1 \text{ if there is phone line on the location} \\ 0 \text{ if otherwise} \end{cases}$$

Thus the entire category takes on the value "zero" if there is no possibility of installing a landline telephone. In Portugal there are 4 internet operators. In the first item the number of providers with network in the case study location is directly introduced.

Subsequently and based on the capabilities of the networks, a scale is drawn up, which has a maximum of 7 levels and allows a correlation. The following grades were used: ADSL (1); 3G (3); 4G (4); 5G (6) and fibre optic (7). The aim is to value the most up-to-date option which allows greater speed and reliability in the transmission and/or reception of data.

The network quality is also a factor under analysis; for this item a Likert scale with four levels was implemented. The category 5 infrastructure index is calculated using the formula:

$$I_5 = b_1\left(p_1 \times \frac{Q_1 - 1}{3} + p_2 \times \frac{Q_2 - 1}{6} + p_3 \times \frac{n_3 - 1}{3}\right)$$

Subtitle:

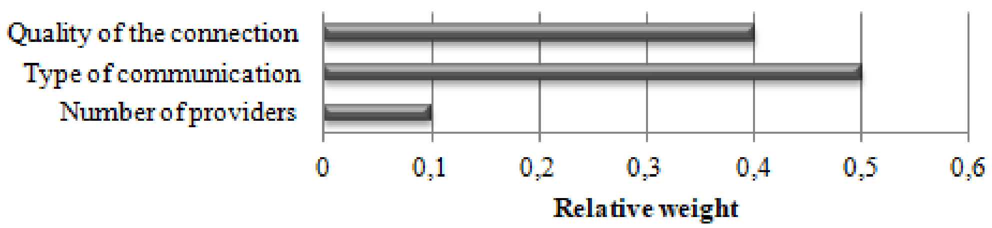
I_5 - value of the fifth index representing in the study telecommunications, for the calculation of the infrastructure index (*Inf*)

$$b_1 = \begin{cases} 1 \text{ landline phone available} \\ 0 \text{ otherwise} \end{cases}$$

Items: i=number of providers; i=2 type of communication; i=3 quality of the connection.

After performing some simulations, the following weightings were established (Figure 9).

Figure 9. *Telecommunications Items and Relative Weights*

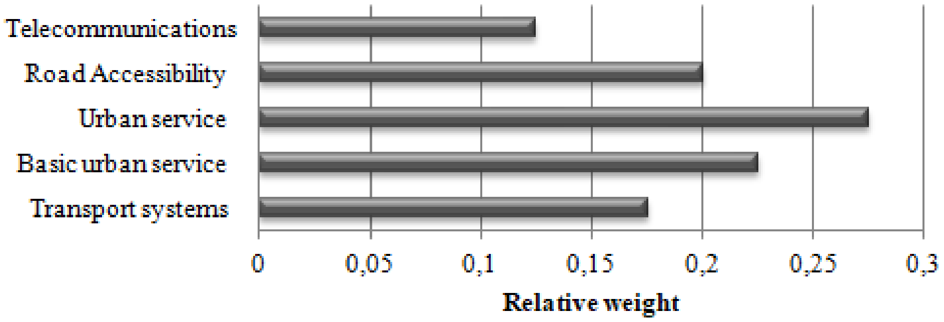


Source: Elsa Negas & Rui Seco RS 2021.

Infrastructure Index Calculation

Following the calculation of the index for each category, the overall infrastructure index is calculated, and it is necessary to assign the weighting to each category; in this case the following weightings were established (Figure 10).

Figure 10. *Infrastructure Categories and Relative Weights*



Source: Elsa Negas & Rui Seco 2021.

The infrastructure index is the outcome of the following calculation:

$$Inf = \sum_{i=1}^{5} f_i I_i = 0{,}175 I_1 + 0{,}225 I_2 + 0{,}275 I_3 + 0{,}2 I_4 + 0{,}125 I_5$$

This comprehensive equation encompasses the weighting of the 5 key categories, in turn resulting from the weighted calculation of the sub-categories that compose them.

Findings

To test the workability of the infrastructure index, its use was experimentally simulated in five distinct locations in the city of Lisbon, with notably different characteristics regarding infrastructure and basic urban services: one in the old urban core, two in central areas with major urban activity and transports connections, and two others on mainly residential areas of the immediate outskirts.

From this first test analysis there were found some variances in results that enable the possibility to perceive between how the existent disparities are reflected in the index outputs.

It can be noticed that the 'Services and Telecommunications' categories are not discriminatory, since their existence and respective quality is homogeneous (consistently guaranteeing a 40% evaluation), but the remaining categories reveal some important differences:

- Intercity transports are not close to all locations, and night transports are not homogeneously available as well.

- The city center has 100% in the services index, but in some places accessibility has constraints, regarding aspects like sidewalk width (very narrow) and the ease and safety of parking.
- Moving away from the center the accessibilities have a 100% evaluation, but not all services are provided within the predefined distance.

The obtained results were:

$$0{,}71 \leq Inf \leq 0{,}93$$

It should be noted that these data refer to a set of points located within the urban area of a city (in this case Lisbon), and therefore reflect the presence of a considerable range of services and infrastructures.

Conclusions

The study of infrastructure commits to a future in which the collection, storage, processing and interpretation of information will be facilitated allowing us to advance our understanding of the urban condition and urban well-being, as pointed Bannister and O'Sullivan (2021) who assert beliefs in the contributions of Big Data[15].

The territorial infrastructure evaluation is intended to assess an area as small as feasible, as it is based on walking times that allow the classification of the access to services, schools and public transport, among others.

Aspects as distinct as mobility, access to transport, its diversity and periodicity, the quality of road connections, access to technology, sanitation, administration and public services, as well as culture and leisure, among many others, are contemplated, permitting to assess the present situation, as also to evaluate the potential for economic and social development.

The consideration of such a large number of items requires the quantifiable treatment of each of them and their total and relative weighting. It is important to recognize the balance between each item in the category to which it belongs and the weighting of the category in the global assessment.

The resultant formula can be applied to any area and with the same pondering factors can be in given cases performed statistical analyses, identification of asymmetries and comparisons between different locations with the same geographical (proximity to rivers, lakes, oceans or inland), demographic, social or employment characteristics[16].

This aggregate index will allow the assessment of the existent infrastructure, aiming at the interpretation of the territory and its potentialities. The aim is to

[15]"We reaffirm a belief that the Big Data contributions of greatest significance and lasting value will be those maintaining the clearest focus on using Big Data to advance our understanding of the urban condition and urban well-being" (Bannister and O'Sullivan 2021).

[16]Although the overview of the calculation for some categories and their items is described basing on the Portuguese context, its transposition to other realities is straightforward.

calculate the infrastructure level in different places, allowing the identification and quantification of asymmetries.

The measurement is performed in percentages, allowing asymmetries to be highlighted.

From the experimental testing of its use to assess infrastructure in different locations in the city of Lisbon it was found that there are noticeable translations of the different conditions in the results obtained, both in the breakdown calculations of the different categories and in the final assessment values. The obtained overall ratings, between 71% and 93%, revealed the differences from central areas with major urban activity to more peripheral and mono-function oriented zones.

These results also show a match to areas inside a consolidated urban area, reflecting the presence of a considerable range of services and infrastructures. The broadening of the tests to less urbanized districts could indicate its suitability for more contrasting situations.

It is important to note that each category can be evaluated individually, but the overall quantification of the 5 categories (including all items from every category and subcategory) in different locations of the same area (urban or rural) will enable the opportunity to promote the rectification of constraints, identifying investment priorities that can lead to a better infrastructure balance in the territory.

Future Developments

The performing of panel data analysis will enable the opportunity to calculate the infrastructure index for different locations over different time periods, which will make it possible (in the medium and long term) to verify trends of evolution and to calculate variations.

It will then enable the use of the calculation method as an evaluation system, to produce analytic data that can then be cross-referenced with other indicators, like the development level, education level, unemployment rate or birth rate.

Testing the implementation of the aggregate index in the field in different geographic realities of the territory will help to fine tune the balance and relative weighting of the categories and sub-items. This will constitute the next stage of the research.

As the study is part of a broader research dedicated to the estuary of the Tagus River and its territory, it will focus on the analysis of the heterogeneity of the estuarine environment, identifying and studying the differences in the levels of urbanization of this territory.

In the future, the goal will be to apply the index to different locations and periodically review the items and their quantification due to the technologies upgrading and the increasing significance of the implementation of eco-sustainable solutions.

The urban infrastructure level calculation method is intended to constitute an operative contribution to the analysis of the territory, considering however that, as André Corboz stated, other kinds of knowledge are also indispensable for its understanding, in addition to statistics and quantifications, enabling it as a semantized and *discursible subject*[17].

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References

Addie J-P (2022) The times of splintering urbanism. *Journal of Urban Technology* 29(1): 109–116.

Angheloiu C, Tennant M (2020) Urban futures: systemic or system changing interventions? A literature review using Meadows' leverage points as analytical framework. *Cities* 104: 102808.

Ascher F (2001) *Les nouveaux príncipes de l'urbanisme: la fin dês villes n'est pas à l'ordre du jour.* (The new principles of urban planning: the end of cities is not on the agenda). La Tour d'Aigues, Éditions de l'Aube.

Bannister J, O'Sullivan A (2021) Big Data in the city. *Urban Studies* 58(15): 3061–3070.

Bourdin A (2010) *L'urbanismed'après crise.* (Post-crisis urbanism). La Tour d'Aigues: Éditions de l'Aube.

Carr LJ, Dunsiger SI, Marcus BH (2010) Walk score as a global estimate of neighbourhood walkability. *American Journal of Preventive Medicine* 39(Nov): 460–463.

Choay F (1999) O reino do urbano e a morte da cidade. (The reign of the urban and the death of the city). In *Projecto História* #18. São Paulo: UCP.

Corboz A (1983) Le territoire comme palimpseste. (The territory as palimpsest). In *Diogène* #121, 14–35. Paris: Gallimard.

Currie G (2010) Quantifying spatial gaps in public transport supply based on social needs. *Journal of Transport Geography* 18(1): 31–41.

Direcção-Geral do Ambiente - Direcção de Serviços de Informação e Acreditação – DGA-DSIA (2000) *Proposta para um Sistema de indicadores de desenvolvimento sustentável.* (Proposal for a sustainable development indicators system). Lisbon: DGA-DSIA.

Greer S, Watson M (1987) Mental adjustment to cancer: its measurement and prognostic importance. *Cancer Surveys* 6(3): 439–453.

Mumford L (1938) *The culture of cities*. New York City: Harcourt, Brace and Company.

Negas E (2021) *Estatística descritiva: explicação teórica, casos de aplicações e exercícios resolvidos*. (Descriptive statistics: theoretical explanation, application cases and exercises). 2nd Edition. Lisbon: Sílabo.

[17]To Corboz (1983), the territory must be recognised for its own character, stemming from its culture and history.

Negas E, Seco R (2020) Cidade, território, urbanidade: parametrização da infraestruturação urbana. (City, territory, urbanity: parameterization of urban infrastructure). In *Formulas in Architecture*, 225–246. Lisbon: Universidade Lusiada Editora.

Nijhuis S, Jauslin D (2015) Urban landscape infrastructures. Designing operative landscape structures for the built environment. *Research in Urbanism Series* 3(1): 13–34.

Preston J, Rajé F (2007) Accessibility, mobility and transport-related social exclusion. *Journal of Transport Geography* 15(3): 151–160.

Silva PB (2017) *A mobilidade nas cidades: infraestruturas de transportes públicos urbanos*. (Mobility in cities: urban public transport infrastructure). Lisbon: Universidade Lusiada Editora.

Simone A, Pieterse E (2017) *New urban worlds: inhabiting dissonant times*. Cambridge: Polity Press.

Turker D (2009) Measuring corporate social responsibility: a scale development study. *Journal of Business Ethics* 85(May): 411–427.

Wofsy SC (2011) HIAPER Pole-to-Pole Observations (HIPPO): fine-grained, global-scale measurements of climatically important atmospheric gases and aerosols. *Philosophical Transactions of the Royal Society A: Mathematical Physical and Engineering Sciences* 369(1943): 2073–2086.