eMOTIONAL Cities

Mapping the cities through the senses of those who make them

DELIVERABLE 6.3

Report on the indicators characterizing the built environment II

FEBRUARY 2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº945307. This document reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains.

Project Title	*e*MOTIONAL Cities: mapping the cities through the senses of those who make them
Deliverable	D6.3 – Report on the indicators characterizing the built environment II
Work package	WP6 – Evidence-based knowledge
Task	T6.1 – Identification of the urban artefacts that mostly affect indicators of physical and mental health
Number of pages	42
Dissemination level	Public
Leader	IGOT
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File name	eMC_2024.29_D6.3_Indicators_BuiltEnv II.pdf
Versions	V1: 29-02-2024 (Peer review) V2: 04-03-2024 (Submitted version)
Revision	-

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Executive summary

This document consists of deliverable 6.3: “Report on the indicators characterizing the built environment II, belonging to the “WP6 – Evidence-based knowledge” of the *e*MOTIONAL Cities project, and it’s part of the “Task 6.1 - Identification of the urban artefacts that mostly affect indicators of physical and mental health”. The technical report is an updated version of the deliverable D6.1, in regard to the indicators characterizing the built environment, as it documents an extensive set of indicators and metrics that we are using, and can be used by anyone, to study the relation between the urban environment we live and work, with people’s health/illness, and wellbeing. To make this report as useful as possible to readers, instead of showing a list of indicators and their mathematical formulas, we organize a table with 6 (six) descriptors for each indicator and metric. It is our intention to make it more comprehensive, useful, and findable to all. The indicators and measures are organized according to the table below as a template.

TEMPLATE for Metrics

Description	A short description of the indicator and measures.
Inputs (optional)	An identification of the data needed for the indicator/measures to be operational
Experiment	An identification of the experiment where the indicator and measure is being applied (cf. D5.1)
Threshold / Benchmark	An explanation on how the indicator and measure can be interpreted and if it can be suitable for benchmarking.
Clarification	An explanation on how it can be used for measuring the influence of the built environment on people’s health
Application example	Cases where the indicator/metric were applied
Reference	A few references of research works where the indicator/metric was applied

1. Introduction

1.1. Background

Data is critical to make informed, efficient, and knowledge-based decisions. Without data we could not make solid interpretations and arguments, and convert them into facts, produce ideas, create evidence, and build knowledge. Without data there isn't good diagnosis which in turn are key to derive tailored decisions towards sustainable solutions, reduce uncertainty and improve decisions efficiency. However, just having data doesn't help. To understand the impact of built environment, and the urban artefacts that make it up, we need good quality data in order to develop high-quality measures. (Ross, et al., 2009). The interplay between built environment and human health and wellbeing is highly complex, and the research work that has been done so far in this matter is still in an early stage and in many cases its exploratory work. Therefore, the indicators and metrics here documented are the result of a permanent work-in-progress, which stems both from a continuous review of the literature and from the ongoing cross-analysis related to WP4, WP6, and WP7, and the neurosciences experimentation (WP5).

The report is in line with, and contributes to, the objectives of the WP6 – Evidence-based Knowledge, namely:

O6.1 - Data Fusion between WP4 and WP5 data sets and other urban health, perception and well-being datasets in order to identify as well as quantify the impact of different urban environment categories on people's physical and mental health: this objective is twofold: a) it merges the collected and pre-processed datasets from WP4 & WP5 experiments into a well-being dataset (in a synchronized format ready for subsequent steps of cross-referencing and dynamic mapping); and b) it deals with the characterization of different urban environments and the definition of the relevant indicators and metrics. For the physical environment, measures such as urban form, urban density, attractiveness, open space ratio, and urban greenery will be identified and associated with quantifiable metrics. The metrics will be prepared so that they could be related to previous WPs.

O6.2 - Flag and measure different types of urban artefacts based on their impact on people's physical and mental health in relation to age, gender and vulnerable groups (see WP5): under this objective, the urban features and artefacts will be characterised and clustered based on previously identified metrics (O6.1) in order to identify exemplary zones due to their specific characteristics. The goal is the identification of a set of properties that affect health, not only in relation to demographic (age and gender), socio-economic variables and mobility patterns; but also focusing on people belonging to vulnerable groups. The outcomes will introduce new evidence for eMOTIONAL cities considering a universal design approach that can be accessed, understood and used to the greatest possible extent by all people regardless of their age, size, ability or disability.

O6.4 - Create a set of eMOTIONAL indicators on urban health: through this objective, we will introduce the indicators for quantifying eMOTIONAL cities based on physical and mental measures. This would be one of the core outcomes which will be applied to different cities to bring evidence-based knowledge and to support the design of a baseline scenario (O6.5) and conceptual meta-model for WP7.

Moreover, it is worth saying that this report, on the indicators characterizing the built environment, follows three rules of thumbs: data sustainability; data utility; and data usability. Policymakers and decision makers rely more and more on data to make informed decisions and increase policies efficiency. At the same time, the way the report is written and presented, aims to amplify the readers level of education upon the relationship between the built environment and human health, to pursue one of the project objectives which is raise awareness and foster community empowerment that leads to a more active public participation in the local policies and actions, towards an urban design that promotes health and wellbeing. Researchers, planners and urban designers can also find guidance in this report.

There are different types of data, and data can vary in form (quantitative or qualitative); structure (structured, semi-structured and unstructured); source (captured, derived, exhaust, transient); producer (primary, secondary, tertiary, synthetic, crowdsourcing and citizen science data); type (indexical, attribute, metadata, supplementary) (Kitchin, 2014; Townsend, 2013). And, at the same time, there are different ways to characterize the built environment (Ross, et al., 2009; Orion, 2016) regarding public health.

1.2. Objectives

This report's main objective is to frame a set of measures that can act as indicators to evaluate and build evidence on how, and how much, the built environment can affect people’s physical and mental health and well-being. More precisely, the selected scales and measures will be used to characterize mental health and wellbeing within the project during Experiment 1 (“Brain as predictor of emotional urban places), Experiment 2 (“Understanding the neural processing of urban space through naturalistic stimuli”), Experiment 3 (“Mobile sensing of stress and emotional effects of daily urban experience”) and Experiment 4 (“Outdoor neuroscience experiments”). A detailed description of each of these experiments can be found in deliverable D5.1, and some of its applicability, in D5.3.

The measures are organized into domains, which in fact outlined the way in which this report is structured. Moreover, a comprehensive explanation is provided for each indicator and metric, as well as an example of case studies where it has been applied, and a few references from where it can be consulted.

1.3. Report structure

The report delves into the indicators and metrics characterizing the built environment, and for that reason Physical and Mental wellbeing indicators - which were psychophysiological and individual indicators to measure people’s perception, personality, cognition and behavior, that were reported in the D6.1 - Report on the indicators characterizing the built environment I and measures on physical/ mental health of people I, were now left out. However, the relation between the built environment and human health is always highlighted. The report is now organized into 3 main sections, whose indicators included, all together characterize the built environment and allow to measure the physical/mental health. 1) **Urban form** (consists of the physical environment, and non-physical environment indicators that are considered to measure built environment influence on people’s health); 2) **Environmental and climatic** (by considering climate and urban nature as integral components of urban planning and design, cities can enhance the health and wellbeing of their residents); 3) **Urban health** (urban health indicators are of utmost relevance for the understanding of the interplay between urban built environment and human health. From individual level to community and city-wide level, these indicators are key to pinpoint areas that are more or less healthy, to support more targeted and tailor-made policy actions.

This report documented on the extensive summary matrix, presented in the D6.1, which is a wrap up compilation of indicators and metrics - inspired by the variables and metrics identified on D4.1 and adapted considering WP5 - Neuroscience experiences -, to measure how, and how much, the built environment impacts on people's physical and mental health, and wellbeing. It presents a detailed description and experiment related information and it is organized by categories and metadata items. Moreover, all the data resulted from the applications of these indicators and metrics are being used to fulfill the tasks and objectives of the different WPs (WP4, WP5, WP6, and WP7), for the different experiments and case studies of the *e*Motional Cities project, eg. Lisbon, London, Copenhagen, Lansing, and Tartu, and are being stored in the project Spatial Data Infrastructure (SDI), as part of the WP3 responsibility.

2. Urban form

2.1. Introduction

Urban form is commonly used to describe the physical characteristics of a city. However, urban form can also encompass non-physical features such as socioeconomic and demographic aspects (Dempsey, N., 2010), which is why we decided to include in this section a subsection dedicated to socioeconomic and demographics aspects that are equally important to profile city neighborhoods, and often point out as confounding variables when trying to relate physical features with health/illness conditions. Moreover, we consider including in this section a set of indicators and metrics that we have organized in other two subsections, e.g. Space syntax metrics, and physical environment metrics.

2.2. Space syntax

Space syntax is an evidence-based tool, that encompasses a set of theories, methods and techniques for the analysis of the urban form and urban, that provides better understanding of the relationship between the built environment and human behavior.

Axial Graph Analysis Metrics:

Connectivity

Description	Connectivity refers to the structure of the network of public spaces and their links. In Space Syntax, connectivity accounts for all direct connections each axial line have to other axial lines in its immediate vicinity.
Inputs	Four variables influence the study of street connectivity: link, accessibility, least-angle and centrality. (Mohamad & Said, 2014)
Experiment	Exp.4 - Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	The number of intersections is divided by the sum of intersections and cul-de-sacs/dead ends/stub streets, giving a total possible score of 1.0 in areas where there are no cul-de-sacs/dead ends/stub streets. An index of 0.75 or higher is recommended to provide adequate connectivity. Under the Link-Node methodology, the number of links (sum of segments between intersections on through streets and cul-de-sacs in a system) is divided by the number of nodes (intersections and cul-de-sac ends). A perfect grid system would have an index of 2.5. Several municipalities have adopted indices of between 1.2 and 1.4 as the minimum desirable range for acceptable connectivity. (Van Nes & Yamu, 2021)
Clarification	Connectivity of streets and neighborhoods are associated to accessibility (more circuits to from A to B) and directly influence people's movement within an area, facilitating walking, and cycling, and promoting the use of the public space and socialization, and active lifestyle, which in turn enhances health and wellbeing.
Application example	Connectivity was a spatial analysis relevant to the SkyCycle project in London. There are several techniques for assessing connectivity. Two of the most common are the U.S. EPA's methodology contained in the 2002 Indicator Dictionary – Smart Growth Index and the Link-Node approach outlined by Reid Ewing's book 1996 Best Development Practices. EPA's methodology relates the number of intersections in an area to the number of intersections plus the number of cul-de-sacs and dead-end streets.
Reference	Mohamad, W. W., & Said, I. (2014). A review of variables of urban street connectivity for spatial connection. In IOP Conference Series: *Earth and Environmental Science* (Vol. 18, No. 1, p. 012173). IOP Publishing. DOI: 10.1088/1755-1315/18/1/012173 Yamu, C., Van Nes, A., & Garau, C. (2021). Chen, YR., Hanazato, M., Koga, C. et al. (2022). https://spacesyntax.com/project/skycycle/

	https://www.london.gov.uk/programmes-strategies/transport/cycling-and-walking/mayors-vision-cycling

Integration (HH)

Description	Integration is a measure of centrality that enables the measurement of the relative accessibility of space within a system in terms of the number of direction changes. Integration analysis could be local or global, and it can be calculated at different radii from the centre of the environment. R=3 pedestrian movement R=10 vehicle movement R=n Global Integration (total number of directional changes)
Inputs	Street-to-street transitions needed from a street segment to reach all other street segments in the network using the shortest paths. (Hillier *et al.,* 1984)
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	Highly integrated spaces have high integration value and highly segregated spaces have low integration value
Clarification	It refers to a measure of accessibility which is related to how easy or difficult is to move in an area. It's also associated to wayfinding and navigation.
Application example	Global integration analysis of Berlin in the area of the Berlin Wall; Global and local integration analysis of Oslo.
Reference	Hillier, B. et al., 1984; Van Nes and Yamu, 2021

Entropy

Description	Entropy is a measure of the distribution of locations of spaces in terms of their depth (changes in direction) from a space rather than the depth itself. It quantifies the degree of difference between the integration values of different spaces. So, if many locations are close to a space/node, the depth from that space/node is asymmetric, and the entropy is low. If the depth is more evenly distributed, the entropy is higher. This measure can express culturally significant topological differences among spatial layouts.
Inputs	Neighborhood layout
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	High values correspond to greater deep, and to more segregated spaces; evenly distribution, the more difficult it is to reach other spaces.
Clarification	This measure can express culturally significant topological differences among spatial layouts. (https://www.spacesyntax.online/term/entropy/) Entropy shows the level of space accessibility. The higher the entropy value, the more difficult it is to reach other spaces of space and vice versa. Relativised entropy takes account of the expected distribution from a space of origin (node/axial line). That is, in most cases, you would

	expect the number of nodes encountered as you move through the graph to increase up to the mean depth and then decline afterwards. The technicalities of entropy and relativised entropy is based on Shannon's measure of entropy and information theory.
Application example	The study carried out by Coutrot, A., Manley, E., Goodroe, S., et al. (2022), about the influence of entropy and therefore on navigation ability, from 38 cities across the world is a good application example of the relevance of the indictor and people cognition and mental health. Street network orientation, configuration, and entropy in 100 cities around the world using OpenStreetMap data and OSMnx (Boeing, 2019), is another good example.
Example/ Reference	Hillier et al., 1987; Turner, 2001; Turner, 2004 Coutrot, A., Manley, E., Goodroe, S., et al. (2022).

Local measure: Control

Description	The control value is the degree of choice that each space represents for its immediate neighbors as a place to move to.
Inputs	Neighborhood layout
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	Spaces which have a control value greater than 1 will have strong control, those below 1 will be weak control spaces
Clarification	Control measures what degree of choice each space represents for its immediate neighbors as a space to move to It can be associated with navigation and wayfinding in a specific type of urban design.
Application example	A city street or road, which is connected to many one-connected other spatial typologies, e.g. squares, promenades, pocket plazas, etc.
Reference	Hillier et al., 1987

Angular Segment Analysis Metrics: Connectivity

Description	Segment connectivity consists of counting the number of connections from a street segment to all other adjacent street segments
Inputs	Street network lines
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	The greater the number, the greater the connectivity
Clarification	Connectivity of streets and neighborhoods are associated to accessibility (more circuits to from A to B) and directly influence people's movement within an area, facilitating walking, and cycling, and promoting the use of the public space and socialization, and active lifestyle, which in turn

	enhances health and wellbeing.
Application example	The study from Chen et al., 2022 carried out in Japan, building evidence on the association between street connectivity and depression among older adults is a good example. Results show that living in high-intersection density and high-street-connectivity areas were associated with lower incidence of new depression.
Reference	Van Nes and Yamu, 2021 Mohamad, W. W., & Said, I. (2014). Chen, YR., Hanazato, M., Koga, C. et al. (2022).

Angular Connectivity

Description	The cumulative turn angle to other lines
Inputs	Street network
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	The longest route with the lowest angular deviation wins over the shortest route with a larger angular deviation. The sharper the angular turn from a segment, the higher the step is weighted.
clarification	Streets and roads networks are characterized by ty geometrical properties, which have a direct effect on people behavior and movement, and therefore on type of activities and economic life, and street vibrancy. Such characteristics in turn affect elicits specific emotions and feelings in regard to space.
Application example	N/A
Reference	Turner, 2004 Molinero, C., Murcio, R. & Arcaute, E. (2017).

Angular Segment Integration

Description	What angular segment analysis adds to integration of the axial analysis is that each street segment is weighted by the angle of its connection to other street segments. The angular integration is obtained by performing either the Tulip analysis in different bin (4-1024 bins) or the Full Angular analysis. Different metric radii can be selected: 400–800m = walkable distances or local accessibility 5,000–8,000m = car-based distances or citywide accessibility
Inputs	Street network
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	Highly integrated spaces have high integration value, and highly segregated spaces have low integration value.

Clarification	Streets and roads networks are characterized by ty geometrical properties, which have a direct effect on people behavior and movement, and therefore on type of activities and economic life, and street vibrancy. Such characteristics in turn affect elicits specific emotions and feelings in regard to space.
Application example	N/A
Reference	Turner, 2004 Van Nes and Yamu, 2021

Choice

Description	Choice measures the degree of betweenness and measures the through-movement potentials applying different metric radii. In other words, Choice measures the possibility for each segment to be selected as a part of the shortest route between origin and destination.
Inputs	Street network
Experiment	Exp.4 – Outdoor; Exp 5 - Clinical
Threshold/ Benchmark	When changing direction, people tend to choose routes where the angles between different streets and street junctions are close to 90° or 180°. Urban blocks with rare angles like 30˚ and 60° are presumably difficult to orient, and people tend to get lost.
Clarification	Freeman node betweenness centrality tells us about the node in the network that we need to pass more often when exploring the network space. A space with different nodes with high betweenness values is a space that offers more choice/options for navigation between different points/places in the space.
Application example	A study from Haider and Dhirgham, 2021 exploring the correlation between street centrality and human density reveals urban life was found on organic streets, where vitality, activity, and density existed with high values of betweenness.
Reference	Van Nes and Yamu, 2021 Haider, J. and Dhirgham, A., 2021

Visibility Graph Analysis Metrics: ISOVIST (or Viewshed)

Description	The volume of space visible from a given point in space. It describes the space from the viewpoint of individuals as they perceive, interact with, and move through space.
Inputs	landscape and observer points. Digital 3D surface elevation (in GIS environment)
Experiment	Exp. 2 - Urban/Videos; Exp. 4 – Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	binary 0 - nonvisible; 1 - visible
Clarification	Several studies have explored the relation between isovist and emotions and urban affects, and there's a consensus that an open space with a visual target at a distance triggers positive emotions, relieve and a feeling of safety and openness. which differs from spaces with lower volume of

	visible area, that show an association with high levels of stress (Xiang and Papastefanou (2021). At the same time, there's also many studies upon the association of isovist and mobility behavior.
Application example	The study of Xiang and Papastefanou (2021), and the study of Knoll et al. (2015), linking isovist and urban stress in Hong-Kong, Japan and Darmstadt, Germany, respectively are good examples.
Reference	Van Nes and Yamu, 2021 Xiang, L., Papastefanou, G., & Ng, E. (2021). Knöll, M., Neuheuser, K., Cleff, T., & Rudolph-Cleff, A. (2018) Knöll, Martin & Li, Yang & Neuheuser, Katrin & Rudolph-Cleff, Annette. (2015).

2.3. Physical Environment

Average age of buildings

Description	The average age of buildings considers the year the building was constructed.
Inputs	Year of completion of building construction and localization. Data normally available in the Census
Experiment	Exp. 4 - Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	N/A
Clarification	The older the buildings, the more likely they are to be poorly maintained and the socio-economic conditions of the resident population to be below average
Application example	N/A
Reference	Silva *et al*. (2023). Mapping Urban health across the pilot studies and for specific sites identified as 'hot spots' during the analysis, Deliverable 4.2. eMotional Cities H2020, GA 945307. Ommundsen *et al*. (2023). Analysis of mental health & urban data: The greater Copenhagen Area. Technical report, eMotional Cities H2020, GA 945307. Morgado *et al*. (2023). Methodological report for mapping hot spots in Lisbon. eMotional Cities H2020, GA 945307

Buildings with repair needs ratio (or state of conservation)

Description	The state of conservation of a building or of a built ensemble is important for assessing the quality of the urban fabric and the image and aesthetics of the urban landscape. Normally, high levels of necessary conservation work equate to poorer socio-economic areas.
Inputs	Buildings with repair needs ratio in percentage (%). Data normally available in the Census.

Experiment	Exp. 4 - Outdoor;
Threshold/ Benchmark	The more buildings need repair work, the worse their state of repair. They usually correspond to older buildings; in which case the socio-economic conditions of the resident population are more likely to be lower than average. Level 5 - Excellent (coefficient: 1.2); Level 4 - Good (coefficient: 1); Level 5 - Average (coefficient: 0.9); Level 2 - Poor (coefficient: 0.7); Level 1 - Poor (coefficient: 0.5). (NRAU, 2006)
Clarification	Buildings with repair needs ratio or state of conservation is an universal measure, with different designations and thresholds, depending the geography and context. For this deliverable we present Portuguese references.
Application example	Many municipalities in Portugal adopt the conservation levels established in article 33 of the 'New Urban Lease Regime' (NRAU) in their municipal regulations, namely for the purposes of urban lease provisions (Example: Coimbra City Council). Certification of minimum habitability conditions, part B - building (LNEC, 2011)
Reference	N/A

Average building height

Description	The average building height is obtained from the total height of building of the buildings in a street. The Total Height of a Building is the vertical dimension measured from the threshold elevation to the highest point of the building.
Inputs	Heigh of the buildings
Experiment	Exp. 4 - Outdoor;
Threshold/ Benchmark	The greater the height of the building, the greater the verticality of the urban area, which can mean the occurrence of more limited visual amplitudes / smaller isovist.
Clarification	Depending on the geography and nature of the case, the total height of a building may or may not include other building volumes on the roof (such as chimneys and accessory and decorative elements). The heigh of buildings and urban thermal comfort is a topic of research that associate urban climatic conditions and human health (Gilbert, et al, 2021; Almendra, et al, 2019) . This term should not be used to refer to the height of the façade.
Application example	Study of the effect of variations in building height on the city's breathability. (Chen et al., 2015), and its impact on peoples health.
Reference	Chen et al., 2015) Almendra, et al, 2019

Floor area ratio (FAR)

Description	Floor Area Ratio (FAR) indicates the correlation between the plot area on which the building is constructed and the building floor area that can be used or is allowed to be used. Building floor area is the numerical value, expressed in square meters (m2), resulting from the sum of the areas of all floors, above and below ground, measured from the outside walls
Inputs	Lot Area and Building Floor Area. Building area and Lot area. Floor Area Ratio (FAR) = Total Building Floor Area / Gross Lot Area
Experiment	Exp. 4 - Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	Not applicable as the Ratio varies depending on the population density, construction-related activities, growth patterns, and the nature of the building's space or land.
Clarification	A higher floor area ratio implies an urban or denser construction. A denser built-up environment is point out as an urban stressor factor and therefore negatively related with mental health and wellbeing.
Application example	Study on the relationship between citizens' subjective perception of urban spatial structure and the floor area ratio to delineate city centres and infer a characteristic density threshold. (Wurm et al., 2021)
Reference	Wurm, M., et al., (2021).

Sky View Factor (SVF)

Description	The Sky View factor (SVF) is a measure to quantify the amount of visible sky when standing at a particular point in a given urban environment. It is typically expressed as a ratio of the visible sky area to the total visible area from a given point. This measure is used in urban planning and design to assess the amount of direct sunlight and solar radiation that reaches a particular area. It can also be used to estimate the cooling effect of natural ventilation and to evaluate the potential for urban heat island mitigation strategies based on the morphology of the city.
Inputs	360° images
Experiment	Exp.4 - Outdoor
Threshold / Benchmark	N/A
Clarification	The SVF is influenced by the geometry of the built environment, including the height and spacing of buildings, the location of trees and other vegetation, and the presence of other physical features that obstruct or reflect sunlight. This metric is an important tool for understanding the built

	environment's impact on urban microclimates, and for developing effective strategies to improve human comfort and well-being in urban areas.
Application example	The studies from Dirksen, et al. (2019) and from Qiang et al. (2023) are two good examples of the SVF indicator and its relationship with human health.
Reference	M. Dirksen, R.J. Ronda, N.E. Theeuwes, G.A. Pagani, (2019) Qiang Chen, et al. (2023).

Distance to green spaces

Description	The distance to the green spaces was calculated using the Euclidean distance, which calculates the distance between two points. The distances were then weighted from 0 (corresponding to areas where the distance to green spaces is greater than 300 meters) to 1 (corresponding to areas where the distance to green spaces is 0 meters).
Inputs	European Environmental Agency / Copernicus (2020). But it can also be obtained by satellite image classification
Experiment	N/A
Threshold/ Benchmark	Green spaces up to 300m linear distance
Clarification	As accessibility to health care facilities, the accessibility to urban green spaces is equally important regards to human health, both physically and mentally. Many studies delve into the relationship between green areas and health, highlighting the many health and wellbeing benefits, e.g. psychologic restoration, noise reduction, stress reduction, anxiety reduction, relaxation, improve the mood, enhance cognitive function, encourage physical activity and fight sedentarism, combat hypertension, etc.
Application example	The longitudinal study from Rebecca, et all, show that living in greener areas, or close to green and blue spaces (GBS; eg, parks, lakes, or beaches), is associated with better mental health.
Reference	Nieuwenhuijsen, M., et al., 2022 Rebecca, S., et al., 2023

Density of fast-food outlets

Description	Kernal density of data from 100 Montaditos, Burger King, Burger Ranch, Domino's Pizza, McDonald's, Pizza Hut, Telepizza, KFC, Taco Bell, Subway, Pans & Company, and Papa John's chains
Inputs	OpenStreetMap (OSM) data
Experiment	N/A

Threshold/ Benchmark	N/A
Clarification	The easy access to fast-food suppliers is associated with obesity, hypertension, and cardiovascular diseases.
Application example	The study form Evangelia, et al., shows that accessibility to fast food restaurants is positively associated with the presence of obesity hot spots, while access to green space areas is associated with decreased neighborhood obesity rates.
Reference	Evangelia K., et al. (2020).

Walkability Index

Description	Walkability is a measure of how friendly an area is to walk; walkability supports community health, safety, livability, and reduced car dependence. It describes to which extent a neighborhood is walkable
Inputs	The walkability index score is derived from physical characteristics of the urban environment that support walking including residential density, sidewalk presence and completeness, land use mix, retail floor space ratio, and intersection density
Experiment	Exp. 1 – Brain as predictor; Exp. 2 - Urban/Videos; Exp. 3 – Mobile App; Exp.4 – Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	Score below 25 is car-dependent; score between 50 to 69 is somehow walkable, and above 70 is very walkable.
Clarification	It's a measure that has been associated with the development of healthier urban areas and to promote healthier lifestyles. It consists of various factors that influence the ease, safety, and enjoyment of walking in a particular neighborhood. These factors often include the density of residential areas, the mix of land uses (such as shops, schools, workplaces, and parks within walking distance), street connectivity (how directly streets are linked and how many routes one can take), and pedestrian infrastructure (like sidewalks, pedestrian crossings, and traffic calming measures). The presence of green spaces and the aesthetic appeal of the environment can also contribute to an area's walkability.
Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources Speck, J., (2012). Walkable city. How downtown can save America, one step at a time. 1st Ed., Farrar, Straus and Giroux. New Tork. ISBN: 978-0-374-28581-4

Diversity index

Description	Shannon-Wiener index adaptation to measure diversity through urban legal activities which means functional diversity. The diversity index in urban design stands as a proxy for vibrant streets.
Inputs	The diversity index is calculated based on the number of POI (retrieved via Geofabrik downloads website) - which includes cafes, restaurants,

	churches, theaters, monuments, hotels, parks, etc.), and third places which aren't places where people live (first place), nor a place where people work (second place), rather places where people carry out social activities (mainly social) which indicates places of social interaction -, per specific feature, e.g. street buffer area.
Experiment	Exp.4 – Outdoor; Exp5 - Clinical
Threshold/ Benchmark	normalized on a scale of values from 0 to 1, where 0 represents absence of diversity, and 1 stands for maximum diversity.
Clarification	Such as complexity, the diversity index as impact on people's perception and cognition/emotion, and behavior. More diversity, for instance of health care, gives people a perception of safety; Overall, a more diverse environment captures people attention and encourage to explore and interact. Moreover, urban bio-diversity underpins ecosystem function which are essential for human health and wellbeing.
Application example	N/A
Reference	Marselle, M.R., et al. (2021) Salvador, Rueda, et al., (2022) https://urbanhealth.org.uk/wp-content/uploads/2020/12/Personal-perspectives-on-urban-health-and-wellbeing-report.pdf

Complexity index

Description	The concept derives from the term fractals, introduced by Benoit Mand 1977, which has been used to understand and measure complexity in ma including architecture and city planning. Here we measure street complex on buildings façades visual architecture adopting a quantitative metho counting.
Inputs	buildings façades geometries
Experiment	Exp. 2 - Urban/Videos; Exp.4 – Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	Complexity index range values varies from 1 (low fractal dimension) to 2 (high fractal dimension)
Clarification	The complexity of an urban scene or feature in the context of urban design is associated with positive/good and negative/bad stress (distress) impact on dwellers.
Application example	We have conducted an exploratory study for Lisbon, using empatica 4 wristband to measure stress and cross with the complexity of buildings façades computed through box-counting method, and proof that there's a positive correlation between complexity and stress (good stress).
Reference	Coutrot, A., Manley, E., Goodroe, S., et al. (2022).

2.4. Socieconomic and Demographics

Purchasing Power

Description	Purchasing Power per capita, in euros (€). It reveals the real value of the money, and it reflects how much goods and services one unit of currency can buy.
Inputs	Source: Esri, Michael Bauer Research GmbH (2022).
Experiment	Exp.4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	It's a confounding variable to be considered for the analysis of the experiment 4, as it was revealed by previous analysis, included the ones done in the WP4 to identify hotspots (see D4.2 and the technical reports for Lisbon for instance) that there's a strong correlation between people with low purchase power and mental health issues, e.g. Depression, anxiety and dementia.
Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Unemployed people ratio

Description	Unemployed people ratio in percentage (%). It majors the level of labor force jobless, and it reflects the economic vitality and the the wellbeing of area, either a parish, council, or a country.
Inputs	Such data is normally available in the Census.
Experiment	Exp.4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	It's a confounding variable to be considered for the analysis of the experiment 4, as it was revealed by previous analysis, included the ones done in the WP4 to identify hotspots (see D4.2 and the technical reports for Lisbon for instance) that there's a strong correlation between people that is jobless and active looking for a job, and with low purchase power and mental health issues, e.g. Depression, anxiety and dementia.
Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

People with a low literacy level ratio

Description	This metric refers to people with education level up to 9th grade, in percentage (%), and it reflects the societal development of a region.
Inputs	Such data is normally available in the Census.
Experiment	Exp.4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	It's a confounding variable to be considered for the analysis of the experiment 4, as it was revealed by previous analysis, included the ones done in the WP4 to identify hotspots (see D4.2 and the technical reports for Lisbon for instance) Literacy and education can contribute to improved mental health by reducing stress related to unemployment and poverty. We have found correlation, between low literacy areas and more cases of people diagnosed with mental issues. Other studies (longitudinal) also show that a correlation between higher literacy rates and longer life expectancy. This is attributed to a combination of better economic conditions, healthier lifestyles, and improved access to healthcare services.
Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Population density

Description	A ratio of number of inhabitants per area. It is a measure that can be used to classify urban/rural territories and/or different degrees of urbanization.
Inputs	Number of inhabitants and area size
Experiment	Exp. 1 – Brain as predictor; Exp. 2 - Urban/Videos; Exp.4 – Outdoor
Threshold/ Benchmark	The degree of urbanization typology for Local Administrative Units level 2 (LAU2) - the typology of clusters starts by classifying grid cells of 1km sq to one of the three following clusters, according to their population size and density: ● High-density cluster/urban center: contiguous grid cells of 1 km2 with a density of at least 1 500 inhabitants per km2 and a minimum population of 50 000; ● Urban cluster: cluster of contiguous grid cells of 1 km2 with a density of at least 300 inhabitants per km2 and a minimum population of 5 000. ● Rural grid cell: grid cell outside high-density clusters and urban clusters.
Clarification	There's not much work, as far we know, on crowding and how it affects people cognition and behavior and its influence on peoples health. However, there's evidence that high dense areas are more correlated with

	mental health issues than less dense areas. We'll perform analysis using computer vision algorithms to calculate the density of people in a field of view of a person and cross with several biosignals (EEG; heart rate; EDA; …) to have more insights and see if there's a threshold.
Application example	N/A
Reference	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Degree_of_urbanisation_classification_-_2011_revision#Degree_of_urbanisation_classification. Daza, M.; et al, (2021).

Gender Ratio

Description	This metric refers to the number of males per 100 females
Inputs	Such data is normally available in the Census.
Experiment	Exp. 1 – Brain as predictor; Exp. 2 - Urban/Videos; Exp. 3 – Mobile App; Exp. 4 – Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	N/A
Clarification	Throughout all the experiments we are gender balance. We want to be able to see if there's differences and what are the reasons for that difference, in the psychophysiological signals triggered by the urban features.
Application example	We are analyzing data from fMRI and EEG, and eye-tracking, and Empatica 4, with volunteers' man and women, with different ages, when expose to different built environments.
Reference	Deng Y, et al., 2016. Chaney, Robert., et al, 2023.

Youth people ratio

Description	This metric refers to people being 0 to 24 years old, in percentage (%).
Inputs	Such data is normally available in the Census.
Experiment	Exp. 1 – Brain as predictor; Exp. 2 - Urban/Videos; Exp. 3 – Mobile App; Exp. 4 – Outdoor
Threshold/ Benchmark	N/A
Clarification	It's a confounding variable to be considered for the analysis of the experiment 4, as it was revealed by previous analysis, included the ones done in the WP4 to identify hotspots (see D4.2 and the technical reports for Lisbon for instance).

Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Elderly people ratio

Description	This metric refers to people being 65 years old or above, in percentage (%).
Inputs	Such data is normally available in the Census.
Experiment	N/A
Threshold/ Benchmark	N/A
Clarification	It's a confounding variable to be considered for the analysis of the experiment 4, as it was revealed by previous analysis, included the ones done in the WP4 to identify hotspots (see D4.2 and the technical reports for Lisbon for instance).Studies, and our analysis sptial data analysis, show that areas with elderly residents are correlated with more number of cases diagnosed with health issues, e.g. hypertension, dementia, depression and anxiety.
Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Sentiment Analysis

Description	This metric measures and maps emotions with social media data, specifically through tweet analysis, using geotweets.
Inputs	Twitter data
Experiment	N/A
Threshold/ Benchmark	N/A
Clarification	Urban perception can be captured based on harvesting data from social media which refers to a manifestation of peoples emotions and feelings regarding a specific environment or urban artefact, or event going on in a specific place.
Application example	D4.3
Reference	Chen, Y, et al. (2020) Gibbons, J., et al. (2019)

3. Environmental and climatic

Slope

Description	Measure of the steepness of a walking path (the height difference between two points along a walk)
Inputs	Digital Elevation Model (DEM)
Experiment	Exp. 1 – Brain as predictor; Exp. 2 - Urban/Videos; Exp. 3 – Mobile App; Exp.4 – Outdoor
Threshold/ Benchmark	• <5%—Suitable • 5% < *x* < 8%—Acceptable • >8%—Inappropriate
Clarification	The morphology of the city, whether it is flat or hilly, triggers different psychophysiological signals as peoples move around. The heart rate, the isovist, the perception, cognition, and behavior of pedestrian change within the morphology of the places. Throughout our experiments are exploring the effect of such variable. We'll explore the variable to
Application example	The walkability index is a good example of the relevance of the degree of slope of the city and health, by promoting a more active living. D4.2 and technical reports for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources Speck, J., (2012). Walkable city. How downtown can save America, one step at a time. 1st Ed., Farrar, Straus and Giroux. New Tork. ISBN: 978-0-374-28581-4

Vulnerability to excessive heat index

Description	A spatial modeling was built based on IPMA temperature records and a set of conditioning features (high above sea, exposure, topographic position, distance from the sea). It has consider the HWDI index (Heat Wave Duration Index), according to the criteria of the IPMA (Portugal weather institute) and the World Meteorological Organization, and the criteria of the Directorate-General for Health.
Inputs	Number of days of intensive heat temperature and morphological features, and demographic and health data.
Experiment	N/A
Threshold/ Benchmark	From "inexistent" risk to "high" risk
Clarification	Increased thermal discomfort in the summer can affect human health, by requiring an additional thermoregulatory effort on the part of individuals in order to achieve comfort. With the increase in the magnitude and intensity of extreme heat peaks, or heat waves, we can expect to see greater morbidity and/or mortality from heat-related illnesses. Due to the morphology and urban form, some city areas are more vulnerable than others. At the same time, elderly population, and people already with certain diseases, e.g. respiratory, cardiovascular are more vulnerable.
Application example	To pinpoint such areas, and to further establish some association between other health and demographic variables, we have run some

	LISA analysis. The technical report for mapping hotspots in Lisbon underlines the relevance of this indicator.
Reference	Lisbon Metropolitan Plan for Climate Change Adaption, 2018. https://www.aml.pt/iniciativas/plano-adaptacao-alteracoes-climaticas/

Vulnerability to flash floods index

Description	The metric results from a hydro-geomorphological modeling to determine floodplains areas, based on precipitation and conditioning factors (e.g. characteristics of the hydrographic stream; slope, permeability; vegetation cover/land use; drainage basin area; topography of valley bottoms;
Inputs	Hydrological stream, slope, land use, permeability, basin area, soils.
Experiment	N/A
Threshold/ Benchmark	From "very low" risk to "high" risk
Clarification	People that are more expose to natural hazards show high level of stress, and sleep disorder.
Application example	Technical report for mapping hotspots in Lisbon
Reference	Makwana, N., (2019) https://emotionalcities-h2020.eu/resources/ Lisbon Metropolitan Plan for Climate Change Adaption, 2018. https://www.aml.pt/iniciativas/plano-adaptacao-alteracoes-climaticas/

Normalized Difference Vegetation Index (NDVI)

Description	Normalized Difference Vegetation Index – quantifies the density of vegetation on the ground through the difference between visible and near-infrared reflectance of vegetation cover
Inputs	Multispectral satellite image
Experiment	Exp. 1 – Brain as predictor; Exp. 2 – UrbanVideos; Exp. 3 – Mobile App. Exp.4 – Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	Accordingly, to the WHO (2012), a minimum of 9m2 UGS per inhabitant and an ideal of 50m2 per inhabitant.
Clarification	Many studies suggested, and some have proven, many benefits of greenness exposure on human health, whether physical or mental health. Green urban areas can be derived from different sources, depending on the scale of study areas. In the eMotional Cities project, we decided to use the NDVI as it can easily be replicated by others, adopting the same methodology.

Application example	D4.2 and technical reports for mapping hotspots in Lisbon
Reference	Song, H., et al., 2019. https://emotionalcities-h2020.eu/resources/

Particulate Matter (PM2.5)

Description	Annual mean, in micrograms per cubic meter air (µg/m3).
Inputs	Data collected from city sensors; satellite images; mobile sensors.
Experiment	Exp. 4 - Outdoor
Threshold/ Benchmark	According to the WHO (2021), the annual average concentration of PM2.5 should not exceed 5 µg/m3, while 24-hour average exposures should not exceed 15 µg/m3 more than 3 - 4 days per year.
Clarification	Poor air quality is associated with poor health. Most studies focus their attention on the association between poor air quality and physical health, and little attention is given to the complex array of environmental exposures and air pollutants that affect mental health.
Application example	The finer particles (i.e., PM2.5) can be derived from primary sources (e.g., combustion of fuels in power generation facilities, industries, or vehicles) and secondary sources (e.g., chemical reactions between gases). In outdoor environments, the main sources are location-specific and can be made up of different origins but typically include traffic and transportation, industrial activities, power plants, construction sites, waste burning, fires or fields. PM is capable of penetrating deep into the lung and entering the bloodstream causing cardiovascular (ischaemic heart disease), cerebrovascular (stroke) and respiratory impacts. Both long-term and short-term exposure to particulate matter is associated with morbidity and mortality from cardiovascular and respiratory diseases. Long-term exposure has been further linked to adverse perinatal outcomes and lung cancer. (WHO)
Reference	Bhui, K., et al., (2023). WHO, 2021 https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants

Nitrogen Dioxide (NO2)

Description	Annual mean, in parts per billion by volume (ppbV)
Inputs	Data collected from city sensors; satellite images; mobile sensors.

Experiment	Exp. 4 - Outdoor
Threshold/ Benchmark	According to the WHO (2021), the annual average concentration of NO2 should not exceed ao µg/m3, while 24-hour average exposures should not exceed 25 µg/m3 .
Clarification	As PM2.5 and PM10, nitrogen dioxide (NO2) is also one of the main air pollutants with harmful effects on human health. Its chemical properties mean that this pollutant plays a harmful role in climate change and when exposed to solar radiation, it triggers photochemical reactions that generate organic particles, nitrate, and sulphate, which are measured as PM2.5 or PM10 (WHO, 2021).
Application example	Ambient sources of NO_2 result from high temperature combustion of fuels in processes such as those used for heating, transportation, industry and power generation. Household sources of nitrogen oxides (NOx) include equipment that burn fuels such as furnaces, fireplaces and gas stoves and ovens. Exposure to nitrogen dioxide can irritate airways and aggravate respiratory diseases. NO_2 is an important ozone precursor, a pollutant closely linked to asthma and other respiratory conditions.
Reference	Anenberg, S. et al., (2022). WHO, 2021 https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants

Local Climate Zones (LCZ)

Description	Local Climate Zones (LCZ) are a classification system that divides urban areas into distinct zones based on their physical and thermal properties. This system was developed by a team of researchers to support the study of urban heat islands and their impact on human health and well-being in cities. It divides urban areas into 17 different zones, based on land use, surface cover, and the nature of the built environment. These zones range from densely built-up areas with little vegetation, to open green spaces and bodies of water. It also takes into account the size and shape of urban features, such as building height, street orientation, and the presence of trees and other shading elements.
Inputs	Land use and land cover, buildings, streets, construction materials, etc.
Experiment	Exp.4 - Outdoor
Threshold / Benchmark	N/A
Clarification	The LCZ system is used to map urban areas and identify areas of high urban heat island intensity, which can help guide urban planning and design strategies to reduce the heat island effect and improve human comfort and well-being. It can also be used to study the impact of urban heat islands on energy consumption, air quality, and other environmental factors. Overall, this measure provides a standardized

	framework for characterizing the physical and thermal properties of urban areas, which is important for developing effective strategies to mitigate the negative impacts of urbanization on human health and the environment. Understanding the thermal characteristics of urban areas is of paramount importance for promoting outdoor thermal comfort and managing outdoor heat stress
Application example	The studies from Silva, Lopes, Vasconcelos, from Lisbon and Munich, and also the Huang, Li, Zhao, and Zhai in Beijing, are good examples of the temperature changes and how it affects peoples physical and mental health and wellbeing.
Reference	Silva, T., Lopes, A., Vasconcelos, J. et al. (2024). Huang, H., Li, Y., Zhao, Y., & Zhai, W. (2022).

Urban Heat Island Effect (UHI)

Description	The Urban Heat Island (UHI) is a phenomenon that occurs when an urban area experiences higher temperatures than surrounding rural areas. It is caused by a combination of factors, including the high density of buildings, roads, and other infrastructure in cities, the absorption and re-radiation of heat by urban surfaces, and the release of heat from human activities, such as transportation and industry.
Inputs	Urban surfaces
Experiment	Exp.4 - Outdoor
Threshold / Benchmark	N/A
Clarification	Urban heat islands can have a range of negative impacts on human health and the environment. For example, they can increase the incidence of heat-related illnesses, such as heat stroke and dehydration, and exacerbate air pollution problems by increasing the formation of ground-level ozone and other pollutants. They can also have negative impacts on ecosystems, by altering the timing of seasonal events, such as plant growth and migration, and reducing the availability of water for plants and animals. This metric has been intensively used and applied in different cities as a measure to quantify the effects of urbanization and the necessity of balancing built and natural surfaces in cities. The metric is closely related with LCZ.
Application example	D4.3 and the technical report for mapping the hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Noise Exposure / Pollution

Description	Noise pollution in urban environments refers to the presence of excessive or unwanted noise that can negatively affect human health and well-being.

Inputs	Noise Level (Db)
Experiment	Exp.4 - Outdoor
Threshold / Benchmark	WHO recommends that outdoor noise levels should not exceed an average of 70 decibels (dB) over a 24-hour period, and an average of 53 dB during the night.
Clarification	Urban areas are often characterized by high levels of noise pollution, due to a range of sources, including traffic, construction, industrial activity, and entertainment venues. Exposure to high levels of noise pollution can have a range of negative effects on human health, both physical and mentally, and well-being.
Reference	Hahad, O., Kuntic, M., Al-Kindi, S. et al. (2024).

Perceived Temperature - Universal Thermal Climate Index (UTCI)

Description	The Universal Thermal Climate Index (UTCI) is a measure of the combined effects of temperature, humidity, wind speed, and radiation on the human body. It was developed by an international group of researchers as a tool to assess thermal comfort and heat stress, and to evaluate the potential impact of climate change on human health. The UTCI considers both the physical parameters of the environment and the physiological response of the human body, such as sweating and heat exchange. It is based on a model that simulates the heat transfer between the human body and the surrounding environment and uses standard meteorological data as input.
Inputs	Air Temperature, Relative Humidity, Mean Radiant Temperature, Wind Speed
Experiment	Exp.4 - Outdoor
Threshold / Benchmark	The metric defines perceived temperatures between 9 to 26 °C as a comfort range.
Clarification	The metric is increasingly used by public health authorities, urban planners, and emergency services to assess the risks associated with heat waves and extreme weather events, and to design strategies to mitigate their impact on vulnerable populations.
Application example	The studies from Silva, Lopes, Vasconcelos, from Lisbon and Munich, and also the Huang, Li, Zhao, and Zhai in Beijing, are good examples of temperature changes and how it affects people's physical and mental health and wellbeing.
Reference	Silva, T., Lopes, A., Vasconcelos, J. et al. (2024).

	Huang, H., Li, Y., Zhao, Y., & Zhai, W. (2022).

Wind Exposure / Wind Comfort

Description	Wind comfort in urban environments refers to the level of comfort or discomfort that people experience because of wind driven by the urban artifacts. This metric also has an influence on the thermal comfort of people in outdoor spaces, as well as the dispersion of air pollutants and particles. Different wind patterns created by urban artifacts can influence the perception of wind by people in outdoor spaces in different seasons and times and can affect the occupancy of outdoor spaces for different activities, such as walking, cycling, or sitting.
Inputs	wind speed, wind gust
Experiment	Exp.4 - Outdoor
Threshold / Benchmark	There are several wind comfort criteria's that could be used in this project based on the availability of the data and computational capacities. These metrics are Lawson criteria, Davenport Criteria, NEN 8100 Criteria which considers the annual statistics and frequencies.
Clarification	Urban planners and designers can use information about wind comfort to inform the design of outdoor spaces that are comfortable and usable for different activities and user groups, in order to promote active living and healthier public spaces.
Application example	Several studies have shown that there's an association between wind exposure, and wind orientation, and urban comfort and mental health and wellbeing.
Reference	Janssen, W. D., Blocken, B., & van Hooff, T. (2013) Bos EH, Hoenders R, de Jonge P., (2012) Mikutta, C. A., et al (2022).

4. Urban Health

4.1. Physical health

Hypertension incidence

Description	This metric refers to the number of patients with hypertension, in percentage (%).
Inputs	National Health Institute
Experiment	Ex. 4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	High blood pressure diagnosis has been associated with more depressive symptoms and lower wellbeing, which can lead to increased cardiovascular risk and target organ damage. On the other hand, characteristics of the built environment, e.g. high building density, traffic congestion, and lower connectivity, and less green urban spaces near are associated with more cases diagnosis with high blood pressure.
Application example	D4.3 and technical report for mapping hotspots in Lisbon
Reference	Shahimi, N. et al. (2022). Warembourg,C. et al, (2021).

Obesity incidence

Description	This metric refers to the number of patients with obesity, in percentage (%).
Inputs	National Health Institute
Experiment	Ex. 4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	The disease of obesity is associated with a significant psychosocial burden (Sarwer, 2016). At the same time, the urban characteristics, e.g. proximity to fast food restaurants and shops, and the lack of green areas around have also revealed to be correlated (Evangelia, 2020).
Application example	The study from Evangelia, et al., shows that accessibility to fast food restaurants is positively associated with the presence of obesity hot spots, while access to green space areas is associated with decreased neighborhood obesity rates. D4.3 and technical report for mapping hotspots for Lisbon.
Reference	Sarwer, D.; Polonsky, H. (2016). Evangelia K., et al. (2020). Lopez-Jimenez, F., et al, (2022) Sui, D. (2003)

Patients with Diabetes Mellitus

Description	This metric refers to the number of patients with diabetes Mellitus, in percentage (%).
Inputs	National Health Institute
Experiment	Ex. 4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	People with diabetes are 2 to 3 times more likely to have depression than people without diabetes. Depression, anxiety, and schizophrenia are all things that have been found to be linked to the mental health of diabetics (2022). On the other hand, the built environment influences behaviour, like physical activity, diet and sleep, which affects the risk of type 2 diabetes mellitus (T2DM).
Application example	D4.3 and technical report for mapping hotspots in Lisbon
Reference	Akhaury, K., & Chaware, S. (2022). den Braver, N., Lakerveld, J., Rutters, F. et al. (2018).

4.2. Mental health

Patients diagnosed with depressive disorder

Description	This metric refers to the number of patients diagnosed with depressive disorder, in percentage (%).
Inputs	National Health Institute
Experiment	Ex. 4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	We want to explore the association between the built environment characteristics and the mental illness.
Application example	Some studies are shown that there's an association, especially among older adults, between a poor condition built environment and mental health (depression, and anxiety).
Reference	Chen, YR., Hanazato, M., Koga, C. *et al.* (2022) Wang, L.; et al., (2021).

Anxiety disorder diagnosis incidence

Description	This metric refers to the number of patients diagnosed with anxiety disorder, in percentage (%).
Inputs	National Health Institute

Experiment	Ex. 4 – Outdoor;
Threshold/ Benchmark	N/A
Clarification	We want to explore the association between the built environment characteristics and the mental illness. Some studies are shown that there's an association, especially among older adults, between a poor condition built environment and mental health (depression, and anxiety).
Application example	The studies referenced below are good examples
Reference	Chen, YR., Hanazato, M., Koga, C. *et al.* (2022) Wang, L.; et al., (2021).

Dementia diagnosis incidence

Description	This metric refers to the number of patients diagnosed with dementia, in percentage (%).
Inputs	National Health Institute
Experiment	Ex. 4 – Outdoor; Exp. 5 - Clinical
Threshold/ Benchmark	N/A
Clarification	We want to explore the association between the built environment characteristics and the mental illness. In this particular case of people with dementia, we want to proof that specific urban design interventions are beneficial to the outcomes of people with dementia, namely navigation.
Application example	D4.3 and technical report for mapping hotspots in Lisbon. Exp. 5 – Clinical will focus on this aspect (D5.4)
Reference	Sturge, J., et al., (2021). Marquardt, G., Bueter, K., and Motzek, T. (2014).

Drug prescription of antidepressants

Description	This metric indicates a normalized value of dosage data per number of people, per pharmacy
Inputs	drugs prescription or defined daily doses
Experiment	N/A
Threshold/ Benchmark	N/A
Clarification	Prescribed drugs at pharmacy level gives an idea of the areas where there may be a greater prevalence of certain diseases. Spatial statistics analysis, such as LISA, helps us to understand spatial patterns and correlations with the urban characteristics of the built environment, a well some socioeconomic and demographic indicators.

Application example	technical report for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Drug prescription of anxiolytics (N05B)

Description	This metric indicates a normalized value of dosage data per number of people, per pharmacy
Inputs	drugs prescription or defined daily doses
Experiment	N/A
Threshold/ Benchmark	N/A
Clarification	Prescribed drugs at pharmacy level gives an idea of the areas where there may be a greater prevalence of certain diseases. Spatial statistics analysis, such as LISA, helps us to understand spatial patterns and correlations with the urban characteristics of the built environment, a well some socioeconomic and demographic indicators.
Application example	technical report for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Drug prescription of antidementia (N06D)

Description	This metric indicates a normalized value of dosage data per number of people, per pharmacy
Inputs	drugs prescription or defined daily doses
Experiment	N/A
Threshold/ Benchmark	N/A
Clarification	Prescribed drugs at pharmacy level gives an idea of the areas where there may be a greater prevalence of certain diseases. Spatial statistics analysis, such as LISA, helps us to understand spatial patterns and correlations with the urban characteristics of the built environment, a well some socioeconomic and demographic indicators.
Application example	technical report for mapping hotspots in Lisbon
Reference	https://emotionalcities-h2020.eu/resources/

Patients with chronic alcohol abuse

Description	This metric refers to the number of patients with chronic alcohol abuse, in percentage (%).
Inputs	National Health Institute
Experiment	Exp. 4 - Outdoor
Threshold/ Benchmark	N/A
Clarification	Alcohol abuse, or use disorder often is associated with other mental health disorders, especially depression and anxiety. Mapping the areas where more cases were diagnosed can reinforce and or validate other data analysis, linking built environment, lifestyle, and mental health.
Application example	technical report for mapping hotspots in Lisbon
Reference	https://www.niaaa.nih.gov/health-professionals-communities/core-resource-on-alcohol/mental-health-issues-alcohol-use-disorder-and-common-co-occurring-conditions https://emotionalcities-h2020.eu/resources/

5. Final Remarks

This report presents an update of the first deliverable (D6.1) of the WP6 – Evidence-based knowledge, more specific on the indicators characterizing the built environment, and follows on the ongoing work related to the Task 6.1 “Identification of the urban artefacts that mostly affect indicators of physical and mental health”. Here we identified, described, characterized, and explained the set of urban indicators and metrics in order to discover what type of environment and urban features influence more subjects’ cognitive performance and emotional states.

We also want to underline that’s this report on the indicators characterizing the built environment consists of three parts report, e.g. D6.1 (Report on the indicators characterizing the built environment I and measures on physical/ mental health of people I); D6.3 (“Report on the indicators characterizing the built environment II”), and D6.4 (“Report on the measures on physical/mental health of people II”), that will be deliverable in month 38, and will detail more on the indicators and measures apply on the neuroscience experiments from WP5.

The listed indicators and measure are being applied to different experiments explained in this report and they will be refined based on the applicability of each depending on the characteristics of the datasets. Therefore, the listed indicators and measures will be updated, based on availability of data, in the following tasks of the WP6, and the outcomes of its applicability will inform the WP7 – Scenario discovery.

Moreover, we foreseen these three parts deliverables regarding indicators and metrics, as reference book for researchers and both urban planners and health professionals working on public health and neurourbanism.

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