Opportunities for participatory data collection	The questionnaires are self-reported and as such are reported by the citizens themselves.
Additional information	
References	Nieuwenhuijsen, et al. (2014). Positive health effects of the natural outdoor environment in typical populations in different regions in Europe (PHENOTYPE): a study programme protocol. BMJ Open; 4,4 Grellier et al (2017) BlueHealth: a study programme protocol for mapping and quantifying the potential benefits to public health and wellbeing from Europe's blue spaces. BMJ Open. 2017 Jun 14;7(6):e016188.

8.34 Betweenness centrality

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Betweenness centrality	**Green Space Management**
Description and justification	The betweenness centrality is a mathematical concept of graph theory. It can be measured for a node or an edge, and quantifies the number of times a node or an edge acts as a link in the shortest path between two other green areas with certain size. This can be used to assess the importance of streets and connections in the urban green infrastructure, and to detect missing links. It needs a representation of the urban green network as a graph, an abstract structure that sums up the relation between objects disregarding their actual physical appearance. Here you provide examples: An new NBS can change the physical communication network affecting the pedestrian flows, with repercussions or benefits to economic activities in the area nearby, and conversely on a social level. Dismissed tramway tracks converted in a walkway would change the connectivity of an area, turning a barrier to a space of connectivity between green areas.
Definition	The computation of betweenness centrality in urban green networks needs a representation of the city street network as graph. The edges of a graph represent the streets, while the nodes represent the intersections and NBS. The weight of an edge is the actual distance between two

	nodes. The graph can be undirected for the modelling of pedestrian fluxes, and directed in for vehicular traffic.
Strengths and weaknesses	
Measurement procedure and tool	The betweenness centrality of a node *v* is the sum, on every couple of nodes (*s,t*), of the ratios between the number of shortest paths, between those two nodes *s* and *t*, passing through the node *v* and the total number of shortest paths between *s* and *t*. $C_b(v) = \sum_{s \neq t \neq v \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}$ (1) where $C_b(v)$ is the betweenness centrality for the v node σ_{st} (v) is the sum of shortest paths between two nodes s and t passing through v σ_{st} is the total number of shortest paths in the graph between s and t. This can be calculated for edges (i.e., streets) too. $C_b(a)$ is the betweenness of an edge. The formula is virtually the same, but the path has to pass through the entire edge and not just through a node. $$C_b(a) = \sum_{(s,t) \neq a} \frac{\sigma_{st}(v)}{\sigma_{st}}$$ In graphs representing urban networks, it could be more convenient to use a special case of the betweenness centrality, called stress centrality $C_s(v)$, which does not account for equivalent shortest paths since in most urban context given two nodes there is only one. $$C_s(v) = \sum_{s \neq t \neq v \in V} \sigma_{st}(v)$$ Tools: graph representation and centrality computation softwares or libraries, like: Osmnx, NetworkX, GraphTool, BoostGraph.
Scale of measurement	Neighbourhood and city scale
Data source	
Required data	- Urban graph: an abstract representation of the street networks of a city or neighbourhood, where the links between green spaces and NBS with certain minimum area represented by streets and nodes

Data input type	- Municipality databases - Open sources like Open Street Map - Proprietary sources like Google, TomTom etc.
Data collection frequency	Before / after the project's implementation, to characterize it is effects on the local environment
Level of expertise required	It requires some kind of training, but it can be related to generally known concept such as congestion.
Synergies with other indicators	Connectivity of green spaces and Accessibility indicators have similar aspects, measuring the availability of green areas or the network of green areas in an urban area.
Connection with SDGs	SDG 11 Sustainable Cities and Communities, SDG 13 Climate action, SDG 15 Life on land
Opportunities for participatory data collection	Citizens can upload data to a specific website, where a database is created to gather information from users.
Additional information	
References	Barabási, Albert-László. Network science book. Boston, MA: Center for Complex Network, Northeastern University. Available online at: http://barabasi. com/networksciencebook, 2014. Swyngedouw, E. and Kaika, M. (2003) The Environment of the City… or the Urbanization of Nature, in A Companion to the City (eds G. Bridge and S. Watson), Blackwell Publishing Ltd, Oxford, UK. doi: 10.1002/9780470693414.ch47 Jeff Speck: Walkable City, North Point Press, 2013. Andrés Duany, Jeff Speck, Mike Lydon: The Smart Growth Manual, McGraw-Hill Education, 2009. Nature4Cities, D2.1 - System of integrated multi-scale and multi-thematic performance indicators for the assessment of urban challenges and NBS. https://www.nature4cities.eu/post/nature4cities-defined-performance-indicators-to-assess-urban-challenges-and-nature-based-solutions. Nature4Cities, D2.2 - Expert-modelling toolbox Nature4Cities, D2.3 – NBS database completed with urban performance data https://www.nature4cities.eu/post/applicability-urban-challenges-and-indicators-real-case-studies Nature4Cities, D2.4 - Development of a simplified urban performance assessment (SUA) tool