POSSIBLE INDICATORS FOR THE EVALUATION OF THE PERFORMANCE OF A BIOPHILIC URBAN ECOSYSTEM

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ABSTRACT

As a sustainable design strategy, biophilic design incorporates natural elements into the built environment aiming to create healthy living settings. Indicators are one of the strongest communication tools in design for the provision of a resilient and sustainable human-nature relationship. They support all stages of policy-making, from designing policy frameworks, setting goals and tracking progress, to improving communication between government bodies and other actors involved in the process. Within this context, indicators function as performance measuring tools in designing and planning of biophilic cities. Despite the well-known benefits of biophilic design to human health and well-being, very few cities are systematically implementing biophilic design applications due to lack of practice, technical knowledge, established standards and procedures. This research aims to identify a set of possible indicators for the monitoring of a biophilic city by evaluating the functioning of the components of its ecosystem and the effectiveness of urban policies. The proposed indicator set targets to demonstrate how effectively a biophilic city achieves its goals and objectives as well as constitute a ground for the transformation of cities into biophilic cities by supporting the improvements for proposals of future planning. These indicators represent an initial attempt to develop a self-assessment tool for the investigation of the success of targets and goals related to the creation of a biophilic urban ecosystem. Establishing performance targets for the assessment of progress and developing these even further to test the set of indicators in a pilot study can be considered as a future research direction.

Keywords: Biophilic city, Biophilic urbanism, Urban ecosystem, Indicators, Policy-making

1. INTRODUCTION

In recent years, humans have become alienated from the natural world, and to reinforce this connection, planners, architects, designers, policy-makers and researchers have turned their focus to new approaches to environmentally-

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friendly and sustainable design. These efforts have sought to harmonise the design of the built environment with nature (from workplaces, schools and urban parks to residential gardens) to meet human needs by employing biophilic design principles (Benyus, 1997; Kellert et al., 2008; Newman and Jennings 2008; Downton, 2009; Beatley and Newman, 2009; Browning et al., 2014; Beatley, 2016; Birkeland, 2016). As a sustainable design strategy, biophilic design incorporates natural elements into the built environment aiming to create healthy living settings. A biophilic city is a biologically diverse city that picks up on the nature itself, mimics natural systems, and integrates natural forms into buildings along with cityscapes. Briefly, it is a city planned in accordance with nature's organising principles. The biophilic design of a city offers several potential benefits, including improved air quality, climate change mitigation, sustainable water-cycle management, reduced traffic congestion, enhanced food security, improved ecosystem services and urban biodiversity. Additionally, a biophilic city may produce various positive effects on human health including the reduction of stress caused by urban living, promotion of physical activities and mental health, and improvement of comfort, motivation, productivity and creativity (Berman et al., 2008; Grinde and Patil, 2009; Gray and Birrell, 2014; Söderlund and Newman, 2017).

An indicator is *"a policy-relevant variable that is specified and defined in such a way as to be measurable over time and/or space"* (Astleithner et al., 2004, p. 9). It indicates the presence of a problem or condition and helps to understand where we are, which way we are going and how far we are from where we aim to be. It helps us evaluate how well a system is functioning, alerts us when there is a problem and identifies hotspots where an action is required. In urban planning, indicators are used to support all stages of policy-making, from designing policy frameworks, setting goals and tracking progress, to improving communication between government bodies and other actors involved in the process. In addition to providing regular and systematic information on a policy or a development strategy, they provide feedback with respect to obtained results to decision-makers who can use this information to improve performance accordingly (Dizdaroglu, 2019; Yigitcanlar et al., 2015). Indicators need to be scientifically valid, based on available data, responsive to change in the issue of interest, and easily understandable and relevant to the user's needs (BIP, 2011). In the literature, there has been a considerable focus on developing indicator initiatives across multiple scales (e.g., UNSD Sustainable Development Goal Indicators, EUROSTAT Indicators, Europe 2020 Indicators, ISO 37120:2014 Standards, ARCADIS Sustainable Cities Index, WHO Environmental Health indicators, Human Development Index, Switzerland Monitoring Sustainable Development (MONET), UK Government Sustainable Development Indicators, SustainLane U.S. City

Rankings, Community Indicator Projects in the USA/Australia/Canada, London's Quality of Life Indicators, Glasgow Indicators Project, STAR Community Index, Green Star, Green Globes, LEED BREEAM, SITES, CASBEE, BASIX, DGNB, GBI, NABERS, CEPAS, HQE). Even if these initiatives are derived from different datasets and developed at different scales, their common framework is based on addressing the following questions: (1) What is happening to the state of environment and how do humans affect it? (refers to *Descriptive indicators*); (2) What is the current situation? (refers to *Performance indicators*); (3) What can be done to improve the current situation? (refers to *Policy-effectiveness indicators*), and; (4) How do these improvements contribute to our overall welfare? (refers to *Total Welfare Indicators*) (Gabrielsen and Bosch, 2003). Within this context, indicators can be used as performance measuring tools in designing and planning of biophilic cities.

Despite the well-known benefits of biophilic design to human health and well-being, very few cities are systematically implementing biophilic design applications due to lack of practice, technical knowledge, established standards and procedures. This research aims to identify a set of possible indicators for the monitoring of a biophilic city by evaluating the functioning of the components of its ecosystem and the effectiveness of urban policies. The proposed indicator set targets to demonstrate how effectively a biophilic city achieves its goals and objectives as well as constitute a ground for the transformation of cities into biophilic cities by supporting the improvements for proposals of future planning. The research aim is supported by the following research objectives: (1) defining the components of a biophilic urban ecosystem and its design principles; (2) reviewing the international biophilic city practices to develop an indicator-based monitoring system for the performance measurement, and; (3) establishing a self-assessment tool for governments and policy-makers to track their progress on the sustainability of development policies. Therefore, this paper is presented in four sections: Section 1 provides the background and introduction to the study. Section 2 describes the design of the city as a biophilic urban ecosystem by highlighting the importance of using indicators to monitor the progress and evaluating the impact of policy implementation. The potential monitoring indicators are outlined in Section 3; and finally, Section 4 provides a summary and some concluding remarks.

2. DESIGNING THE CITY AS A BIOPHILIC URBAN ECOSYSTEM

The term 'biophilia' is derived from Greek roots, meaning 'love of life and living things'. It was coined by social psychologist Erich Fromm and then popularised and defined by Edward O. Wilson as *"the innately emotional affiliation of human* *beings to other living organisms. Innate means hereditary and hence part of ultimate human nature"* (Wilson, 1993, p. 31). Wilson's concept of biophilia was developed by social ecologist Stephen Kellert and served as a basis for the works of some environmental scholars who considered the application of this idea to urban planning and contributed to the creation of 'Biophilic Urbanism'. The notion of 'Biophilic City' is described by Beatley (2011, p. 17) as:

A city with abundant nature and natural systems that are visible and accessible to urbanites. It is certainly about physical conditions and urban design – parks, green features, urban wildlife, walkable environments – but it is also about the spirit of a place, its emotional commitment and concern about nature and other forms of life, its interest in and curiosity about nature, which can be expressed in the budget priorities of a local government as well as in the lifestyles and life patterns of its citizens.

At multiple scales, implementation of biophilic design may be as follows: (1) *building* – e.g., green roofs, green atriums and sky gardens, green walls, interior spaces receiving daylight; (2) *block* – e.g., green courtyards, housing clustered around green fields, yards and spaces of native species; (3) *street* – e.g., gardens around pedestrian ways, urban trees, Low Impact Development (LID), vegetated swales, and skinny streets; (4) *neighbourhood* – e.g., restoration of water streams, urban woodlands, ecological parks, community gardens, pocket and neighbourhood parks; (5) *community* - e.g., urban creeks and riparian regions, networks of urban ecology, green schools, orchards/forests for the community; and (6) *region* - e.g., estuary systems and flood plains, regional parks and greenspaces, greening of essential transportation corridors (Beatley and Newman, 2013). Beatley (2011) claims that when compared to a green city, a biophilic city is more extensive, and further suggests that a biophilic city consists of the qualities including, infrastructure and physical conditions; residents' activities, attitudes and knowledge; funding, budgeting commitments and government's priorities. More and more in recent years, cities are increasingly developing and implementing biophilic design strategies (The Biophilic Cities Project, n.d.). Table 1 presents various biophilic design strategies successfully implemented in selected cities.

Table 1. Selected Biophilic Cities and Their Design Strategies

City/Country	Implemented policies, plans and programs
Singapore	The Singapore Green Plan 2012
	National Parks Board (NParks)
	The Garden City Fund
	BIOME
	CUGE (The Centre for Urban Greenery and Ecology)
	Singapore Botanic Gardens
	Singapore Garden Photographer of the Year
	Rail Corridor
	Singapore Garden Festival
	Skyrise Greenery
	Trees.sg
	Gardens by the Bay
	The BCA Green Mark Scheme
Birmingham, United Kingdom	Birmingham's Green Commission
	Green Living Spaces Plan
	Nature Conservation Strategy
	Birmingham and Black Country Biodiversity Action Plan
	Liveable Cities Project
	Active Parks
	Green Commission's 'Making Birmingham Greener Healthier" awards
	EcoRecord
Pittsburgh, Pennsylvania, USA	Pittsburgh Parks Conservancy
	Phipps Conservatory and Botanical Gardens
	Open Space, Parks, and Recreation Plan (OpenSpacePGH)
	Tree Pittsburgh
	Sustainable Pittsburgh Initiative
	Pittsburgh Climate Action Plan
	Bike Pittsburgh Strategic Plan
	Venture Outdoors
Austin, Texas, USA	The Imagine Austin Comprehensive Plan
	Urban Forest Plan
	The Balcones Canyonlands Preserve
	NeighborWoods

	My City's Trees
	Brush Pick Up
	Connecting Children to Nature Initiative
	Watershed Protection Master Plan
Milwaukee, Wisconsin, USA	ReFresh MKE (City of Milwaukee Sustainability Plan)
	Urban Ecology Centre
	Centre for Resilient Cities
	Milwaukee County Parks Strategic Plan
	Troy Gardens
	Alice’s Garden
	Cream City Gardens
	Brown Street Academy Schoolyard Greening project
	Groundwork Milwaukee
	Home Grown Milwaukee
San Francisco, California, USA	Green Connections Network
	Ecology Guides
	SF Plant Finder
	Blue Greenway
	Street Parks
	Better / Living Roofs Program
	Standards for Bird-Safe Buildings
	Urban Forest Plan
	Friends of the Urban Forest
Wellington, New Zealand	Towards 2040: Smart Capital
	Climate Change Action Plan
	Our Living City
	Biodiversity Strategy and Action Plan
	An Open Spaces and Recreation Framework for Wellington: 2013–23
	Outer Green Belt Management Plan
	Wellington’s ‘Blue Belt’
	Two Million Trees project
	Piloting ‘Living Walls’
	ZEALANDIA urban ecosanctuary
	Otari Native Botanic Garden and Wilton’s Bush Reserve
	Urban Agriculture Projects

Indicators are one of the strongest communication tools in design for the provision of a resilient and sustainable human-nature relationship, and contribute to policy development, implementation and evaluation in many ways. They: (1) assess the current state of the environment; (2) highlight emerging problems by addressing the effects of human activities on natural systems; (3) draw attention to the impact and effectiveness of current policies; and (4) support policy development for the environmental protection and sustainable management of urban ecosystems. The types of indicators and their level of detail are very important and are dependent on the context of their use (Dizdaroglu, 2016). With the help of relevant indicators, the biophilic qualities of a city can be measured, and can also be expressed as targets/goals in the design of a biophilic city. They provide information to local authorities, practitioners, communities and other relevant actors when evaluating the level of their success and progress over time. During the process of selection of biophilic urban ecosystem indicators, an extensive review of the literature on biophilic city initiatives is conducted based upon an international literature review and analysis of "grey" literature such as documents published by international organizations, governmental agencies and research institutions available on the internet. Published, peer-reviewed literature is searched using Scopus and the Web of Science databases, while Google is used to search the grey literature. The following keywords are used for searching the literature: "biophilia", "biophilic design elements", "biophilic city", "biophilic urbanism", "biophilic urban ecosystem" and "biophilic design practice".

A conceptual framework is required for the building of a coherent set of indicators that guides the indicator selection process and helps to organise indicators in a structured and meaningful way. In the present study, the city is considered as an ecosystem, and therefore the term 'Biophilic Urban Ecosystem' is used instead of 'Biophilic City'. The conceptual framework of the proposed indicator set is built on the components of an urban ecosystem, which is described as *"a dynamic complex system of biophysical and human interactions that evolve through feedback loops, non-linear dynamics and self-organisation"* (Alberti, 2008, p. 20). It consists of four components: (1) *biotic environment* – including all living organisms within an ecosystem; (2) *physical environment* – including non-living components such as water, air, soil, climate, etc.; (3) *built environment* –composed of buildings, pavements and other man-made structures; and (4) *social environment* – referring to the health and wellbeing of the residents living in the urban ecosystem. The following section provides a description of the proposed indicator set related to each component (Table 2). Each indicator will be scored by a pointing system. The scoring range will be based on one point assigned per each effort. Additionally, normalization method will be employed to the indicators with different units (such as % or dBA) to remove the scale effects of different units by converting the original unit into a pointing system. Finally, the performance level of each city will be indicated by how many points they have earned. The data sources for indicators will include literature review, government agencies, city municipalities, NGOs, academic institutions, research groups and satellite imagery.

Table 2. Key Indicators of a Biophilic Urban Ecosystem

Components of the Urban Ecosystem	Indicator name	Description
Biotic Environment	Establishment of a resilient ecological network	The ratio of the total area of connected green spaces to the total area of green spaces in the city and multiplied by 100
	Fauna sensitive urban design	The number of implemented fauna-sensitive urban design features
	Flora sensitive urban design	The number of implemented flora-sensitive urban design features
	Governance of biodiversity conservation	- The number of biodiversity conservation-related policies, rules and regulations - The number of biodiversity research and projects employed by the local authorities
	Environmental education and public awareness	The number of existing initiatives, institutions and activities related to environmental education and public awareness
Physical Environment	Climate change mitigation	The total area of forest cover change within an urban area
	Improved air quality	The annual change in the number of local bird species
	Healthy water systems	Macroinvertebrates survey (Taxa recorded in the water)
	Soundscape quality	The quality of soundscape through measuring noise levels that are associated with various urban green spaces
	Soil quality	The number of implemented vacant land greening projects, that aims to create ecologically valuable areas

Built Environment	Climate responsive urban design	The number of projects applied for climate-responsive urban design
	Green building design	The number of green building projects
	Green transportation	The number of green transport initiatives
	Green infrastructure	The number of green infrastructure projects
	Green consumption behaviours	The implementation of strategies that encourage green consumption behaviours
Social Environment	Opportunities for physical activities	The opportunities that promote physical activity in green spaces
	Socially inclusive community	The efforts taken by the city management to create a socially inclusive community
	Access to fresh and healthy food	The accessibility to fresh and healthy food sources

3. INDICATORS OF A BIOPHILIC URBAN ECOSYSTEM

3.1. Biotic Environment

In this category, the proposed indicators are utilized to measure the progress made in reducing impacts of human activities on biodiversity; approaches to preserving and restoring ecological functions; the efficiency of available conservation policies, rules and regulations; and efforts in environmental education and in the raising of public awareness.

- *Establishment of a resilient ecological network*

To conserve the biodiversity and ecological integrity of urban areas, the connectivity of green spaces should be promoted through establishing ecological networks. Bennett and Wit (2001, p.5) defines an ecological network as *"a comprehensive system of natural and/or semi-natural landscape elements that is structured and managed with the aim of preserving or restoring ecological functions through conserving biodiversity, meanwhile delivering appropriate opportunities for the sustainable use of natural resources"*. Building a sustainable and resilient ecological network maximises ecosystem services while mitigating the habitat loss and fragmentation associated with human activities. This indicator is calculated by the ratio of the total area of connected green spaces to the total area of green spaces in the city and multiplied by 100.

- *Fauna-sensitive urban design*

Maintaining habitat corridors for the movement of wildlife across roads or other man-made infrastructures is one of the keys to the conservation of biodiversity. Wildlife crossing structures, including underpass tunnels, overpasses, canopy bridges, tunnels and culverts, are designed to reconnect habitats and to provide a safe crossing path for wildlife. Fish ladders, placed on or around such constructed barriers as dams, help in fish migration, while bird-friendly building designs are necessary to prevent bird collisions and mortality. Light pollution at night should be avoided to protect the migratory and breeding patterns of wildlife. Creating habitat steppingstones for wildlife in back yards, patios and balconies, and the use of green walls and roofs also promote ecological interactions in cities. Suggested habitat interventions include providing floral diversity for food and shelter, birth baths, fountains and pools, nesting boxes, rocks, brush/log piles, bee walls and insect hotels. This indicator measures the number of implemented fauna-sensitive urban design features.

- *Flora-sensitive urban design*

Landscaping with native plants offers many benefits. Being adapted to the local environmental conditions, they require less maintenance, while also being resistant to diseases and pests, attracting pollinators and accommodating wildlife. Sidewalk landscaping is an essential component of the urban ecosystem. Specifically, street trees not only provide a wildlife habitat, but also come with many environmental and social benefits. Residential gardens create a significant habitat for threatened and endangered native species. Tree protection policies should be developed in order to keep trees in good health through the mitigation of damage caused by construction works. As a new concept 'Urban Rewilding' helps in the creation of space for biodiversity in urban areas. Developing a network of rewilding sites within the city can allow the reintroduction of extinct species by creating an environment in which they can thrive and disperse. This indicator measures the number of implemented flora-sensitive urban design features.

- *Governance of biodiversity conservation*

Formulating and implementing effective policies, rules and regulations aimed at sustainable biodiversity is a fundamental principle of good governance. Such policies, rules and regulations should provide different levels of protection, while ensuring the long-term conservation of natural resources. For instance, a 'Biodiversity Strategy and Action Plan' is mandatory prior to setting targets and strategies for the management of protected areas and other ecologically important natural assets, as well as a Nature Conservation Strategy, Endangered

Species Protection Regulations, an Urban Forest Strategy and a Green City Plan. Furthermore, annual government budgets, public or private donations, and grants are crucial forms of financial support for biodiversity conservation research and projects. This indicator measures the number of biodiversity conservation-related policies, rules and regulations as well as the number of biodiversity research and projects employed by the local authorities.

- *Environmental education and public awareness*

Environmental education improves people's knowledge, perception and attitudes towards the creation of a resilient environment and society. It should start at an early age in schools, where curricula can be supported by biodiversity courses, workshops, nature excursions, planting programs and hands-on learning activities, such as school gardens. By connecting children with nature-based approaches, future generations will be motivated, having gained knowledge and skills in the application of conservation activities. Public awareness events need to be organised to encourage participation in conservation projects. Community involvement can be promoted through the organisation of a variety of biodiversity-based activities, such as annual festivals, exhibitions, workshops, eco-tours, environmental training programs and volunteer projects for all ages. Conservation-oriented institutions (e.g., natural history museums, seed banks, arboretums, botanical gardens, herbaria, insectaria and wildlife sanctuaries) are important for scientific research, educational practices and, most importantly, protecting biodiversity for future generations. This indicator measures the number of existing initiatives, institutions and activities related to environmental education and public awareness.

3.2. Physical Environment

Proposed indicators in this category provides assistance in measuring the physical environment's quality in terms of climate change mitigation, protection of air and water quality as well as the improvement of acoustic environment and soil productivity.

- Climate change mitigation

This indicator measures the total area of forest cover change in urban areas. Urban forest cover is widely promoted as a key indicator of climate change mitigation. Urban forests provide many advantages to communities by means of filtering air, decreasing surface temperatures, reducing energy demand, improving water quality, controlling stormwater runoff, promoting public health and creating habitats for the support of biodiversity. Measuring and studying urban tree cover functions as a key element in coping with future climate change. In this regard, cities should adopt strategies to protect and increase the urban tree canopy so as to provide healthy and sustainable environments for present and future generations. The diversity, age and size class distribution of the tree species, regional climate, soil and other essential factors that affect tree growth and longevity also need to be considered.

- Improved air quality

Air pollution presents a serious environmental threat to the diversity of life. Not only human health but also the health of all living organisms is affected by the poor air quality. When compared to mammals, bird species are more vulnerable to high concentrations of reactive gases and aerosols in the air due to their unique respiratory systems and so they act as highly effective and sensitive inspectors of air quality (Brown et al., 1997; Sanderfoot and Holloway, 2017). This indicator, therefore, investigates the impact of air quality on bird population richness by measuring the annual change in the number of local bird species. The introduction of new policies and strategies to improve and maintain the presence and richness of bird species is also an important benchmark for the creation of a biophilic urban ecosystem.

- Healthy water systems

A healthy water is a well-balanced system that sustains functioning of the ecosystem and its services, in the meantime, accommodates the health of human beings. This indicator monitors the diversity and number of macroinvertebrates, which are widely recognised as good indicators of the impact of urban activities on water quality (McDonald et al., 1991; Sharma and Rawat, 2009; Agouridis et al., 2015). Some macroinvertebrates (e.g., caddisfly, mayfly, stonefly) are particularly sensitive to physical and chemical changes as well as biological conditions occurring in waterbodies, being less mobile and less able to tolerate contamination. Consequently, macroinvertebrate surveys can be used to determine the success of efforts to transform cities into biophilic urban ecosystems.

- Soundscape quality

As stated by Elmqvist (2013), *soundscape* refers to not only the natural acoustic environment involving sounds of nature, i.e., animal sounds, sounds made by trees, water sounds, sounds pertaining to weather but also ambient sounds made by human beings, i.e., musical composition, sound design, sounds created by various human activities such as activities creating mechanical sounds originating from the utilization of industrial technology. The evaluation of soundscape can be used to assess the biophilic quality of an urban environment. Several studies have shown that natural sounds (e.g., rustling leaves, bird song and water sounds) in urban greenery mitigate the impacts of unwanted sounds such as road traffic or construction noise (Gidlöf-Gunnarsson and Öhrström, 2007; De Coensel et al., 2011; Jeon et al., 2012; Galbrun and Ali, 2013; Radsten-Ekman et al., 2015; Hao et al., 2016; Hedblom et al., 2017). Contact with nature also influences human's physical health and psychological wellness by promoting peacefulness and relaxation. This indicator analyzes the quality of soundscape through measuring noise levels that are associated with various urban green spaces.

- Soil quality

According to Doran and Parkin (1994), soil quality can be defined as *"a soil's capacity to function within an ecosystem, and land-use boundaries to maintain biological productivity, support environmental quality, and promote plant and animal health"*. Soil is a vital resource for healthy ecosystems, and there is an increasing need to protect soil quality to improve biodiversity and the many services provided within the ecosystem by soil biota. Soils suitable for growing native plant species need to be protected within the city. Vacant lands and other neglected spaces with good soil quality support plant growth and development, and so can be transformed into vibrant green spaces such as community gardens, urban farms or educational gardens. Therefore, this indicator measures the number of implemented vacant land greening projects, that aims to create ecologically valuable areas.

3.3. Built Environment

Indicators that are being proposed in this category measure the built environment's quality with regards to climate responsive urban design, sustainable building design, green transport, green infrastructure and green consumption.

- Climate-responsive urban design

Rapid urbanisation has a huge impact on climate, causing extreme weather events, increased surface temperatures and greenhouse gas emissions, while also threatening biodiversity. Biophilic design addresses these challenges by promoting the design of comfortable and healthy environments through the incorporation of climatic parameters into the process of urban planning. These climatic parameters which include temperature, wind, humidity, precipitation and solar radiation should be kept in mind particularly when designing the urban built environment and morphology, the building typology and green spaces (Amado et al., 2016). Among the main advantages provided by climate-responsive urban design; energy efficiency, urban heat island effect mitigation, improvements in both thermal comfort and quality of environment may be given as examples. This indicator measures the number of projects applied for climate-responsive urban design.

- Green building design

This indicator investigates the number of green building projects. Green building rating tools minimise the negative impact of buildings during the design, construction, maintenance, renovation and demolition stages. Major categories in this regard include sustainable sites, water efficiency, energy/atmosphere, materials/resources, indoor environmental quality and landscape design (Chen et al., 2015). Recently, several green building programs have started to integrate biophilic design standards into their assessment scheme, such as the Living Building Challenge, the WELL Building Standard and LEED. Furthermore, the application of biomimicry in architectural design (also applicable in various fields including; energy, transport, agriculture, medicine, etc.) is an emerging practice that refers to the emulation of an organism, along with that particular organism's behaviour or an ecosystem's aspects with regards to pattern, matter, method or process of construction or function.

- Green transportation

This indicator investigates the green transport initiatives in the city. Green transportation aims to minimise car use, and to reduce traffic congestion and the environmental damage caused by transport. Being a cost-efficient, pollution-free, land resource- and space-saving transport system, green transportation is convenient for the use of all types of travellers. Cycling and walking are both essential components of a green transport strategy. In order to provide better life quality to residents, designing highly accessible, interconnected and adequate green spaces including bike paths and pedestrian ways is crucial. Other modes of green transportation include public transport, electric vehicles, hybrid cars, biofuel-powered buses, and so on. Moreover, wind-powered cars, and solar-powered trains, boats and planes are ongoing projects that promote clean technologies for a sustainable future (García-Olivares et al., 2018).

- Green infrastructure

This indicator investigates the number of green infrastructure (GI) projects. It includes both engineered and natural environmental systems that can be implemented at various scales (Pauleit et al., 2019). On a small scale, GI reduces the pressure on buildings through green roof systems, roof gardens or living walls. GI manages stormwater runoff by using permeable hardscapes in parking lots, driveways and sidewalks. In landscape design, GI can take the form of rain gardens, bioretention systems, vegetated swales, constructed wetlands or street trees. Large-scale GI, on the other hand, such as urban parks, forests and green riverbanks, promote habitat and wildlife conservation. Grey water reuse and rainwater harvesting systems are important GI practices for the creation of a water-sensitive city. Lastly, rehabilitating and restoring degraded landscapes, in other words, transforming brownfields into green spaces, can make a tremendous contribution to strengthening the functions and services of the ecosystem in urban areas.

- Green consumption behaviours

This indicator investigates how the city encourages its citizens to adopt greener consumption behaviours. A biophilic urban ecosystem requires the implementation of strategies that encourage green consumption behaviours (GCB), as a concept that refers to a broad range of environmentally responsible purchasing and consumption practices. Barr et al. (2005) categorise GCB into three main groups: (1) purchase decisions (e.g. buying energy efficient appliances, consuming locally produced foods, avoiding aerosol products or toxic detergents); (2) water and energy saving habits; and (3) reusing or recycling. Psychological factors such as perceived consumer effectiveness (i.e. the belief that the consumer's individual efforts can make a difference for the protection of the environment), self-efficacy, social responsibility, price, and health and safety issues influence consumption patterns (Gilg et al., 2005). Also, the environmental knowledge of consumers and green advertising stimulate their attitudes towards and intentions to buy green products.

3.4. Social Environment

In this category, the proposed indicators are utilized to measure the quality of the social environment regarding strategies that promote physical activity in green spaces, efforts to create a socially inclusive community, and access to fresh and healthy food.

- Opportunities for physical activities

This indicator examines the opportunities that promote physical activity in green spaces. Studies conducted recently demonstrated several different health benefits offered by Urban Green Spaces (UGSs) (Faber Taylor and Kuo, 2011; Beil and Hanes, 2013; Bell et al., 2014; Grazuleviciene et al., 2015; Annerstedt van den Bosch et al., 2016; Beatley et al., 2018). In a biophilic urban ecosystem, UGSs should offer opportunities for physical activities, such as multiple sports fields, outdoor courts, playgrounds for children and seniors, fitness stations, bike paths and walking/jogging circuits. Furthermore, the quality of UGSs strongly affects usage patterns. The richness of vegetation and the presence of wildlife, the existence of water bodies and diverse amenities for all social groups, easy and direct accessibility, and high levels of maintenance, safety and security influence the frequency and duration of visits and further enhance urban environment's quality.

- Socially inclusive community

This indicator examines the efforts taken by the city management to create a socially inclusive community. Social interaction is important for people of all ages and abilities (i.e., universal design). Designing accessible, inclusive and attractive UGSs enhances social networks and builds a strong sense of community (Mace et al., 1996). Some examples of community involvement efforts that UGSs offer are: (1) park activation programs, such as nature walks, outdoor exercise programs, festivals, concerts and film screenings; (2) voluntary works in which residents can participate to clean up parks and plant trees; (3) after school activities or seasonal outdoor programs for children and young people; (4) establishing safe and supervised parks for disadvantaged groups; and (5) therapeutic landscapes and healing gardens for the treatment of mentally, physically and emotionally challenged people. In addition to UGSs, a city needs to include other biophilic spaces where people with various social and ethnical origins to come together, interact with each other and build relationships accordingly. Safe and socially cohesive neighbourhoods increase the use of these spaces, resulting in lower violence and crime rates.

- Access to fresh and healthy food

This indicator measures the accessibility to fresh and healthy food sources. A biophilic urban ecosystem helps to promote access to fresh, healthy and low-cost food through creating possibilities for the local food production. As part of the local food infrastructure, urban agriculture can be encouraged through community gardens, urban orchards, city farms, institutional gardens, commercial farms, backyard gardens, and vertical and rooftop farming. The benefits of urban agriculture are numerous, from improving human nutrition and health, to supporting the local economy and biodiversity conservation. Urban agriculture also contributes to the building of social networks, as well as food education and awareness. Local governments play a crucial role in increasing community food production and creating healthy communities in terms of the development of policies and plans aimed at supporting production, processing, distribution and waste management processes.

4. CONCLUSION

As the world population continues to urbanise at unprecedented rates, health risks resulting from poor environmental quality increase, and at the same time, new hazards to health are being introduced in urban areas, such as those that are: (1) *air pollution related* – acute and chronic respiratory illness, asthma, lung cancer, cardiovascular disease, neurobehavioral effects; (2) *water pollution related*

– tropical diseases, malaria, schistosomiasis, typhoid, cholera, polio, filariasis, hepatitis A, yellow fever and other viral, bacterial and parasitic diseases, gastroenteritis, eye, ear and skin infections; (3) *soil pollution related* – cancer, nervous system damage, neuromuscular blockage and depression of the central nervous system, kidney and liver damage; and (4) *noise pollution related* – sleep disturbance, cardiovascular effects, poorer work and school performance, hearing impairment (WHO, 2002). These health problems are leading the search for nature-inspired solutions.

It is well documented that the conservation and enhancement of natural assets in urban areas is vital, for numerous reasons, involving climate change mitigation, improved air quality, energy conservation, stormwater management, reduced risk of natural hazards, biodiversity conservation, and most importantly, improved health and the quality of urban life. As stated by Beatley (2016, p. 3):

Human beings require to be in contact with the nature and the environment of nature surrounding them. Their environment needs to be flourishing, joyful, fruitful and to lead meaningful lives. Nature cannot be optional. It is a crucial qualification of the modern urban life. In cities, preservation and restoration of existing nature that already exists and discovering or creating ways to grow and introduce new nature forms are paramount challenges of the twenty-first century.

Based on this perspective, there is a need to develop and implement biophilic design strategies to promote green and healthy environments.

Indicators play an important role in informing local authorities, practitioners, communities and other relevant actors about the state of the environment, whether it is improving, worsening or being maintained without change, and in providing information of any changes. Indicators are categorised in many ways; however, it is performance indicators that play an important role in policy formulation, demonstrating how effectively a city is progressing towards an intended goal. In this regard, this study proposes a group of performance indicators for monitoring the performance to observe and assess a biophilic urban ecosystem's qualities, and functions as a series of 'design principles' for guiding future development plans. These indicators represent an initial attempt to develop a monitoring system for the investigation of the success of targets and goals related to the creation of a biophilic urban ecosystem. Establishing performance targets for the assessment of progress and developing these even further to test the set of indicators in a pilot study can be considered as a future research direction.

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