Adoption of Service-Oriented Architecture for Biophilic Service Provisioning Processes: Limitations and Possibilities

Farhad Daneshgar (farhad.daneshgar@vu.edu.au)  
Victoria University

Rahim Foroughi  
University of Sunderland

Babak Abedin  
Macquarie University

Nava Tavakoli Mehr  
Iran University of Science and Technology

Atefa Youhangifard  
Islamic Azad University, Tehran

Research Article

Keywords: biophilic services, biophilic city, service-oriented architecture, urban planning

Posted Date: March 17th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2600768/v1

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Abstract

Many governments have recently shown strong interest in providing more green spaces for the benefit of their citizens. These benefits include recreational enjoyment, health and wellbeing, and biophilic assets/economy. This study analyses the nature of biophilic services as a pre-cursor for identifying high-level requirements of an ICT application for managing biophilic service-provisioning processes in biophilic cities. To achieve the above goal the study adopts a functionalist research paradigm that views biophilic services as part of the biophilic city the latter being a complex network of ecosystems that together promote and sustain solidarity, stability, and sustainability. With its macro-level orientation, the functionalist approach focuses on the needs of its citizens.

1 Background And Scope Of Study

The current urbanisation trend suggests that by 2050 an estimated 70% of the urban areas of the planet will be used for urban dwellers (Zhang & Li, 2016). On the positive side however, many governments have recently shown strong interest in providing more green spaces for the benefit of their citizens. These benefits include recreational enjoyment, health and wellbeing, and biophilic assets and economy. This strategy is achieved by combining biophilic services with urban spaces while preventing destruction of biophilic sources. The current study is an early attempt in enhancing the effectiveness of biophilic service provisioning processes in urban planning through the adoption of a user-centric computerized system.

The ontological assumption of the study is that biophilic services are services provided by various stand-alone systems that are linked together to make the major infrastructure of the biophilic cities (Beatley & Newman, 2013). In line with the above argument a recent study also suggests that in land management decisions, urban planners must fully understand the link among ecosystems and their spread and synergies (Powers, Ausseil & Perry, 2020). For the management of the linked biophilic service provisioning processes the current study adopts service-orientation architecture (SOA) as the initial phase of developing the system. Steps of research design and structure are explained below.

As the first step towards achieving the goal of the proposed biophilic SOA the current study explores from the existing literature various attributes, dimensions, and conceptualizations of biophilic services. This is followed by an integrative review of the literature on the roles and trends of ICT in urban planning focusing on biophilic service provisioning planning and management. Next step provides an overview of the current literature on SOA as the design paradigm for developing the proposed system, along with the highlights of high level functional and non-functional requirements of the proposed biophilic SOA.

2 Biophilic Services

One study divides biophilic research in two major groups: (i) studies on biophilic design (Nikolaidou et al., 2016), and (ii) experiences that are initiated by the above studies and various dimensions of those
experiences (Russo et al., 2017). Another group of studies investigate economic, health, medical, and educational benefits of biophilic elements (Jennings, Larson & Yun, 2016; Hunter & Luck, 2015).

The following sections provide an integrative review (Whittemore & Knafl, 2005) of biophilic services focusing on types of biophilic services (3.1), operationalization of biophilic services (3.2) and standard topology for biophilic services (3.3). These concepts in turn constitute foundation for understanding the requirements of the proposed biophilic SOA, the latter is discussed in Sections 4 and 5.

2.1 Types of Biophilic Services

Some researchers define biophilic service as ecological subsystems for enjoyment and human well-being (Boyd and Banzhaf, 2007). Others define it as “aspects of ecosystems utilized (actively or passively) to produce human well-being” (Fisher et al, 2009), “flow of services and benefits provided by ecological assets during some assessment period” (Bateman et al., 2011), or “provided because of using ecological asset over some period” (Boyd & Banzhaf, 2007). Fisher & Turner (2009) however argue that the above researchers do not consider aesthetic values, cultural dimension, and recreational aspects of the biophilic services. Others argued that if there is no human beneficiaries, the elements, functions and processes of biophilic services should not be considered as true services. For example, Teeb (2010) and Maes et al. (2016) define ecosystem services as benefits are provided directly and indirectly to the well-being of people beneficiaries. A narrowed and specialized approach to the biophilic services addresses the latter as natural assets supplied by earth in the form of wood and food (Spanenberg et al., 2014). And finally, Wallace (2007) regards biophilic services as benefits provided to people from ecosystems as a result of ecosystem management. What is revealed from the above studies is that biophilic services includes various processes and conditions, are characterized as direct and indirect services, implicit/explicit services, and can be measured.

One study by el-Baghdadi & Desha (2017) provides a Six-Ecosystem-Services-Decision cascade and consists of a conceptual framework with three iterative parts. The framework can be used to facilitate decisions related to evaluation, justification, and optimization of the services and its component parts. The core argument and ontological assumption underlying the above study is that green spaces contribute to the health and well-being of those who live and work in urban areas. Such services in turn will enhance people's physical fitness and reduce depression.

Based on the theoretical perspective of Teeb (2010) a study by Larondelle, Haase & Kabisch (2014) provides a holistic categorization scheme for ecosystem services. The scheme suggests the following typology of ecosystem services in four categories:

_Provisioning ecosystem services_: This is the resource-based dimension of biophilic services and includes outputs materialized from eco-systems including food, water, medicine, wood, timber, and several other resources.
Regulating ecosystem services: This category includes materials that balances air conditions such as temperature and moisture, quality of water and soil, and control of storm water, flood, and diseases.

Habitat or supporting services: These services are foundation to all other services that aims to provide spaces for organisms to live by creating biodiversity. Other services may include maintaining diversity among plant and animal.

Services related to the cultural ecosystem: This category includes benefits from non-material, psychological, cognitive, and health sectors that can be potentially obtained by the citizens of biophilic cities. These benefits are normally obtained through contact with green spaces in the living and work environments.

Because of the specific characteristics of biophilic services, our study adopts a functionalist paradigm in designing computerized systems for designing the proposed biophilic Service-Oriented Architecture (SOA). The study asserts that ecosystem planning and management processes can be enabled, automated, initiated, and facilitated by various functions provided by integrated biophilic SOA.

2.2 Operationalization of Biophilic Services

One major pre-requisite for characterizing the proposed biophilic SOA is standard and operationalized definitions of various biophilic services and associated indicators. A recent study provides an approach based on nature for operationalization of the ecosystem services. The study implies that there should be an integrated urban policy that incorporates policies related to the spatial planning and practices with biophilic planning practices (Scott et al., 2016). Another study called “Final Report on the Horizon 2020 Expert Group” (Solutions, 2015) outlines the following four interrelation objectives for a nature-based planning approach for the conceptualization of biophilic services:

“To enhance sustainable urbanisation through protection of essential ecosystem functions and promoting urban regeneration through the adoption of nature-based approaches.

To restore functionality of degraded ecosystems and their services.

To develop climate change adaptation and mitigation through redesigning human-made infrastructure and production systems as natural ecosystems, or developing nature-based “frugal technologies” for lowering energy use by integrating grey with green and blue infrastructure; and

To adopt appropriate and relevant risk management processes to manage crises and resilience by utilising nature-based design that combines multiple functions and benefits such as pollution reduction, carbon storage, biodiversity conservation, reducing heat stress, and enhanced water retention” (Ibid).

The above nature-based objectives are consistent with those of the proposed biophilic SOA, and imply multifunctional functions and service that incorporate “drainage management; habitat provision; ecological connectivity; health and well-being; recreational space; energy reduction; and climate change”
This would then suggest a set of interventions such as designing city-wide networks of biophilic subsystems, multifunctional parks in urban areas with recreational facilities, cooling and flood alleviation services, and streetscapes for water retention, integration of living with built systems including green walls and roofs to reduce heat stress (Ibid). Kazmierczak et al. (2014) emphasizes on the need for exploring potential capabilities that land can provide including biophilic services including disaster management systems etc.

In a more recent study (Czucz et al., 2021), the “UN System of Environmental-Economic Accounting Experimental Ecosystem Accounting” (SEEA EEA) provided a condition typology of ecosystem that can partly reduce the ambiguity surrounding various definitions of biophilic service. This condition typology introduces six categories that are categorized into three major categories “abiotic”, “biotic”, and “landscape-level” characteristics (Ibid). The study claims that the above typology leads to a definition of a ecosystem that incorporates an ‘information structure’. This information structure component in turn can become a sub-part of the service operationalization component within the software service components of the proposed biophilic SOA.

Overall, the proposed biophilic SOA can benefit from a combination of the above conceptualizations in the following ways:

• establishing a common language and a shared understanding of biophilic services
• making various service assessments in various biophilic cities more comparable
• developing a structure for aggregation of biophilic services, and
• creating a model for selection of variables and indicators in the proposed biophilic SOA.

The above biophilic-specific roadmap relates to the three “prototype” classifications that reflect “conceptual clarity” and “practical usefulness” that have been long discussed in the community of ecological and environmental sciences (Harwell et al., 1999). These templates are:

• the essential characteristics of ecosystem (Harwell et al., 1999)
• the ecological integrity typology (Czúc et al., 2021; Tiemey et al., 2009; Faber-Langendoen et al. 2019)
• the classification of essential variables explaining biodiversity (Pereira et al., 2013; Navarro et al., 2017)

The authors of the current study perceive potentials in using the above three prototypes as a starting point for classifying various biophilic services. Details of such scheme and its application to the proposed biophilic SOA implementations are beyond the scope of the current study and constitute authors’ future research.

3 Urban Planning, Biophilic Services, And Ict
As a precursor to understanding high-level requirements of the proposed biophilic SOA, this section provides a brief review of the past and present ICT applications in the domain of urban planning. According to Masnavi, Gharai & Hajibandeh (2019) one main challenge in urban planning is to plan settlements in a way that humans enjoy a quality of life guided by sustainable principles. Jennings et al., (2016) and Hunter & Luck (2015) categorize these benefits as economic, health, and recreational benefits. In other words, the three elements ‘biophilic services’, ‘health of citizens’, and ‘organization of the city’ are major elements of any urban plan that should be linked together (Powers, Ausseil & Perry, 2020).

Most of the current ICT-based solutions focus on solving infrastructural problems in development of urban spaces such as enhancing mobility of people and resources and eliminating negative effects of the activities of citizens (Bachanek, 2018). The idea was to keep the cities’ natural resources free from pollution and environmental degradation. These systems supported urban planning processes such as water management, air quality and various resources in urban areas, and maintaining integration addressing environmental protection and sustainable development. A brief review of the applications that have been used in urban planning is provided below.

Telecity is an early example of a computerized urban planning application that applies information technology to enhancing mobility and other public services where residents can access specific IT services (Siembab, 1996). Smart city is a more holistic concept that incorporates various city concepts into a single architecture (Silva et al., 2018; Alvi et al., 2016). Despite all existing developments, there seem to be inadequate conceptualization of the term smart city, and this is a barrier for fully understanding the concept. A recent study by Kim, Sabri & Kent (2021) proposes a generic framework for both defining and evaluating smart cities by using three core objectives that a typical city would want for its improvement. These are “productivity, sustainability, and livability” (Ibid). The author of the current study considers this as a major achievement in the development of user-centric urban planning computerized application; most previous applications were focusing on the off-the-shelf technologies as the first step in developing the system.

ChangeExplorer is another application that encapsulates hardware and software in a smart watch application (Wilson, Tewdwr-Jones & Comber, 2019). This application manages the process of citizen feedback through a digital wearable watch that enables individuals to participate in a participatory urban planning process. Similarly, an open-source device has been designed and developed by which participants can share their thoughts. The system encourages citizens to express their thoughts and ideas by drawing and speaking words (Wilson & Tewdwr-Jones, 2020).

Silva et al. (2018) proposed a Big Data Analytics experimental architecture for smart cities that enhances effectiveness of Urban Big Data (UBD) exploration in urban planning in smart cities. One recent study provides an assessment framework for the quality of municipal services that is based on SERVQUAL, AHP and Citizen’s Score Card (Afroj et al., 2021).

Most of the above applications are enabled because of technological achievements in some area within the ICT industry; these achievements in turn found their way into the urban planning domain. In other
words, the initial step in the development life cycle of the above ICT systems has been primarily rooted in the ICT innovations (we call it technology-centric design) rather than being based on in-depth analysis of the user requirements as a starting point in system development life cycle. One distinct feature of the current study is that the requirements analysis of the user stakeholders of the system, that is beneficiaries of biophilic services, guided our design of biophilic SOA as a technological artefact and not vice-versa. This is demonstrated in more detail in Sections 4 and 5. We argue that such design approach is more sustainable and agile for responding to emerging opportunities and changes in the citizens’ requirements. The ICT design paradigm for the proposed biophilic SOA is explained next.

4 Biophilic Service-oriented Architecture (SoA)

The SOA is a software design paradigm for distributed systems. In an SOA design, each component provides services through a communication protocol in a network (Bogner, Zimmermann & Wagner, 2018). Based on the SOA design paradigm, functions provided by an SOA-base system for the management of biophilic sources and services would depend on clear definitions and defined characteristics of the service, as well as the net benefit of those services to the service beneficiaries. Technology providers of a future biophilic SOA will be facing several additional challenges because currently there is no unified operationalization scheme for biophilic services; and this is due to the nature-based ecological condition of these services. For example, there is no agreed upon compiler for mapping biophilic services into a language that is understandable by the computer system, and vice-versa. These challenges can be translated into the SOA system requirement analysis. In the current study the SOA system requirements analysis refers to the identification of, and defining, user expectations of the proposed system. Ideally, such requirements are expected to match with the functions and services that the system provides to its users. These requirements are generally divided in two major categories of ‘functional’ and ‘non-functional’ requirements and are discussed next.

5 Functional And Non-functional Requirements Of Biophilic Soa

In the current study, functional requirements refer to the features or behaviors of the proposed biophilic SOA system that developers of the system must implement to enable beneficiaries of biophilic services to accomplish their tasks or receive benefits (adopted from Overby, Bharadwaj & Sambamurthy, 2006). Non-functional requirements on the other hand define how the system should perform. Some examples of non-functional requirements include loading time, quality of service, and system agility. As mentioned earlier, the quality and suitability of the functions performed by the proposed biophilic SOA is closely related to the cohesiveness and clarity of the dimensions of biophilic service definitions and classifications. In section 2.2 an argument started on the recent attempts for achieving further conceptualization and typology of biophilic services. These include the condition typology of ecosystem proposed by the “UN System of Environmental-Economic Accounting Experimental Ecosystem Accounting” (SEEA EEA) (Czucz et al., 2021) and four benefits that the proposed biophilic SOA can receive from the above typology. We also discussed three “prototype” classification schemes proposed by
various researchers as a conceptual framework for partial clarity and practical usefulness of ecosystem services. This argument is further continued in the following paragraphs.

The classification scheme of ecosystem services provided by Teeb (2010) draws a clear line between biophilic services and biophilic benefits. However, it does not explain how these services and benefits can be managed. Later, La Notte et al. (2017) identified one major challenge in managing and coordinating the provision of biophilic services; that is, a lack of consistency in concepts, terminology, and definitions among different ecosystem elements. To address the service definition challenge the above study proposes a new conceptualization for ecosystem services with appropriate techniques for the assessment and measurement of services. It combines *biomass, information, and interaction*. These terms were adopted from system ecology where information is considered as a subset of interactions, biomass is biological material resulted from living/dead organisms, and interactions occur as components may affect one another (Jørgensen, 2012).

The current study claims that the renewed conceptualization of ecosystem services by La Notte et al. (2017) can lead towards a full identification of two main functional requirements of the proposed biophilic SOA, that is, (i) facilitation of the flow of information or communication, and (ii) supporting interactions through coordination of, and collaboration among, various elements of biophilic city. These are two major functions that are expected from the biophilic SOA. Successful implementation of the biophilic SOA functions in turn will depend on the following conditions:

1 – Definition of various ecosystem services should be consistent and agreed upon. As one of many examples of such inconsistency, Maes et al. (2019) define ecosystem service as benefits received by people from ecosystems where benefit is “a positive change in well-being from the fulfilment of needs and wants”. La Notte et al. (2017) suggest that the concept should also address negative aspects of ecological services (or disservices). An example of disservice may be efficient rubbish collection.

2 – Another critical aspect that also contributes to the ambiguity of ecosystem service definition is whether the abiotic services be included in the definition of the services obtained from ecosystem. The European Environment Agency asserts that ecosystem services, among other things, depend on ecosystem processes; and the latter also include biotic components (see www.cices.eu). However, La note et al. (2017) argued that abiotic components can play more effective role in delivering some services than biotic components do. For example, “retention capacity of water in agricultural soils” is largely identified by abiotic factors such as soil particle size (Acosta-Domínguez et al., 2021).

3 – For the proposed biophilic SOA to be feasible, the relationship between ecosystem services and underlying values that these services create should be clear. As a first step towards achievement of this goal, the current study recommends the adoption of a framework that was developed by Liquete et al. (2013, p. 20). This framework provides a ‘cascade model’ that distinguishes between *functions, services, benefits, and value*. The ecosystem *function* is the potential capability of the ecosystems in delivering the services regardless of its usefulness to humans. The ecosystem *services* on the other hand implies access and demand by humans. In terms of access, La Notte et al. (2017) argue that green areas in urban
regions provides more services for recreational purposes than those green areas in remote areas that are not accessible by humans. The ecosystem *benefits* are positive changes in the well-being of humans because of the fulfillment of human needs; these may include nutrition, health, safety, and enjoyment (Ibid). Maes et al. (2016) define ecosystem *value* as “the contribution of an action or object to user-specified goals, objectives, or conditions” (Maes et al., 2016). Therefore, such values would be dependent on relative scarcity, cultural background, and location; and these values must be expressed in biophysical terms and their effects on human health rather than on monetary terms alone (Ibid). In addition, social values should explicitly involve requirements of all stakeholders (Maes et al., 2016).

Another set of system requirements is *nonfunctional requirements* (NFRs). These requirements reflect how the system functions should be performed (Chung & Prado Leite, 2009). NFRs define system attributes such as system security, reliability of the results, system performance, maintainability, scalability, usability, and agility (Ibid). Scott et al. (2016) raise an additional explicit nature-based solution NFR for the proposed system for operationalization of ecosystem services; and that has been implied by La Notte et al. (2017). The above authors suggested partial solution would be nature-based if the requirement adheres to the Green Computing (Overby, Bharadwaj & Sambamurthy, 2006). Other overlapping NFRs may be environmental consciousness, sustainability, growth, and so on. Failing to meet these requirements can result in a system that fails to satisfy fundamental needs of stakeholders including citizens and urban planners.

One generic standard NFR for the proposed SOA is the end-to-end Quality of Service (QoS) requirement such as throughput, availability, transactional integrity, and reliability across the network and among partners (adopted from Bichier & Lin, 2006). This NFR is expected to raise new opportunities for creating new ideas and solutions for enhancing QoS in the biophilic service networks. In business organizational contexts the QoS standards mainly address requirements and service-level agreements of a single Web service (Web of services) (Gorla, Somers & Wong, 2010). Applying QoS to the biophilic services domain this may be translated into an agreement with, and adherence to both the sustainability requirements as well as the needs of the stakeholders. In terms of system implementation, the latter biophilic SOA, the QoS would be maintained by adopting a combination of IoT and data science technologies and methods where the IoT technology will provide nature-based networks and the data science methods and techniques can monitor sustainability and user requirements. Some examples may include standards for expressing a biophilic service's capabilities, requirements, and general characteristics; standards for authentication and transport protocol selection as well as privacy, security, and other QoS characteristics; and standards for agreement to negotiate and manage services based on QoS attributes.

Currently, due to its context-sensitivity of the NFR characteristics it is too early to categorize these NFRs under a standard scheme. However, the current study derived the following list of high-level NFRs for the proposed SOA system design:

- Regular assessment of expectations of multiple stakeholders in relation to various aspects of the proposed system. We propose adoption of the stakeholder theory (Freeman et al., 2010) for this purpose.
Recognizing the environmental and sustainability demands.
Continuous analysis of the system performance in relation to the specific NFRs of the local context (if applicable).
Addressing both general and ecosystem-specific QoS system requirements.

6 Summary, Discussion, And Future Work

One innovation of the current study compared to the existing technology studies in the domain of urban planning is the theoretical perspective adopted by the current study. As explained in the ending paragraph of Section 3 the system development perspective adopted by most existing technology applications in urban planning has been based on off-the-shelf acquisition of existing technologies and importing those technologies to the urban planning domain with minimal formal requirement analysis of the users of those system. In other words, under such technology-centric approach, the technology has been chosen from the pool of current ICT innovations (such as Internet of Things, Blockchain, Augmented Reality, etc.) and then an attempt was made to fit those technological services to the needs of citizens the latter being reflected in various urban planning processes. The current study however adopts a different approach in system development life cycle planning where the nature of biophilic services has been understood and analyse (step 1), then the needs of citizens and other stakeholders in terms of biophilic services are explored and explicated, independent from ICT. These needs are then expressed by functional and non-functional categories (steps 2 & 3). In step 4 an attempt was made to find appropriate ICT that may possibly satisfy citizens’ service requirements explored in the previous steps.

A study by Akande, Cabral & Casteleyn (2019) challenges the general belief that the adoption of Information and Communication Technology (ICT) for managing the carbon footprint reduction process will enhance environmental sustainability. The study however demonstrates it is possible for a city to be smart but not sustainable and vice versa; and concludes that a common strategy is needed for achieving integrated smart, sustainable, and inclusive growth at a macro/continental level. A similar study by Liu et al (2015) argue that for making the planet more sustainable, massive data must be collected and analyzed from various ecosystems for both operational decisions, as well as for restoring and preserving natural resources. This study proposes an integrated systems approach for data acquisition and analysis. Such proposed integrated system is a direct extension of an agriculture ecosystem enterprise (Saw et al., 2008). Through a similar rational argument, the current study provides high-level functional and non-functional requirements of an integrated biophilic service-oriented computerized system that enhances both the 'smartness’ of a city as well as the 'sustainability' of its natural environment. The full implementation of our proposed biophilic SOA is the subject of our future research and development project.

A study by Kar et al. (2019) introduces a new concept smart nation as the next step after creation of digital or smart city. One major pillar of such smart nation is a national transformation process across diverse institutions including the urban and rural areas of a society. The study further argues that diverse initiatives in sustainability is a key aspect of smart nations rather than greenfield projects. The current
study argues that one major step towards such long-term solution will involve appropriate management of biophilic services based on the specifications portrayed in the current study.

Currently there are several conceptualizations of biophilic services, but no clear agreement has been reached yet on those models. On the other hand, the proposed biophilic SOA would only be viable if there is a universal set of concepts and characteristics for biophilic services, their benefits, and costs. We believe that the realization of such functional requirement will became possible because of the customer-centric approach adopted for analysing user requirements. The current study also identified several other functional and non-functional requirements for the proposed biophilic SOA with each following a similar argument.

The ontological fit between the biophilic services and service-orientation of the SOA design justifies selection of a service-oriented method for development of the proposed resilient biophilic SOA. Such fit will reduce the risks associated with the mismatch of the assumptions about the expected functions of the SOA system and the requirements arising from the beneficiaries of the biophilic services. We also believe that as more precise and innovative taxonomies and conceptualizations of biophilic services come to existence, the modularity of the service-oriented computer design paradigm will enable development of more innovative methods of deploying biophilic services in future.

Two consolidated design paradigms, that is service-oriented computing and context-aware computing, are currently changing the way software services are provided and consumed. Service-oriented computing provides flexible software services, and context-aware computing articulates different states of the context as well as the changing behavior of those services (Cabrera, Franch & Marco, 2017). The focus of the current study has been on SOA design paradigm; and the combination of the two paradigms constitutes one of the authors’ future studies when the development and maintenance of the proposed system is investigated.

In the current study, the main beneficiaries of the proposed biophilic SOA system are perceived to be the citizens of biophilic cities. However, in future studies the requirements of other relevant stakeholders such as environmental planners, policy makers, and regulatory organisations at local and global levels will explicitly be entered into the proposed architectural model.

**Declarations**

**Acknowledgement** – We would like to acknowledge valuable research grant provided by the University of Sunderland, UK, and work done by Mr. Khawaja Ahmed Moin Uddin from Victoria University Sydney for assisting us during various stages of this research project.

**Ethics approval**: NA

**Competing interest**: There is no conflict of interests involved in the preparation of this manuscript both among the authors, and between any of the authors with the entities in outside world.
Authors' contributions: First author 50%, second author 20% and the remaining three authors 10% each.

Funding: NA

Availability of data and material: The only data we used in this research was research articles that are available on the Google Scholar, using our institutional credentials. All such data have been cited within the text.

References


ecosystems services and nature-based solutions in cities/Multifunctional green infrastructure and climate change adaptation: brownfield greening as an adaptation strategy for vulnerable communities?/Delivering green infrastructure through planning: insights from practice in Fingal, Ireland/Planning for biophilic cities: from theory to practice. Planning Theory & Practice, 17(2), 267-300.


44. Silva, B. N., Khan, M., Jung, C., Seo, J., Muhammad, D., Han, J., ... & Han, K. (2018). Urban planning and smart city decision management empowered by real-time data processing using big data analytics. Sensors, 18(9), 2994.


