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Computer-Supported Smart Green-Blue Infrastructure Management

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Abstract

Answering climate change challenges, the paper proposes an intelligent decision support system (DSS) for the management of green-blue infrastructure (GBI). Addressing the gaps identified in other studies, the designed DSS incorporates four key elements: 1/interdisciplinary collaboration among all stakeholders 2/inclusion of practical operation and maintenance activities, 3/main components of distributed DSS, with practical examples of use, 4/consideration of conditions specific to the location. The multi-layered DSS architecture can be implemented as a unified platform that provides a comprehensive, customizable, and flexible framework based on AI tools, big data and analytics, edge computing, cloud, and mobile, IIoT, and biometric system tools. The use of cobots and digital clones alongside humans results in the implementation of hybrid human-machine units. DSS for GBI increases decision-making capacity and can serve as a foundation for the implementation of similar systems by governments and local communities to build sustainable and resilient communities.

Keywords: real-time multi-participant DSS, multi-agent cooperative scheme, Big Data and analytics, geo AI, IIoT and cobots, green blue infrastructure.

1 Introduction

As a result of rapid global urbanization (in 2050 68% of the world's population will live in urban areas, compared to 53.9% in 2015) [37] and a 33% increase in world population by 2050 (3.2 billion people), the negative impact of urbanization on the environment is amplified [8]. Without a holistic, personalized approach and the implementation of concerted simultaneous global measures, this negative impact correlated with the spatial interdependence of neighboring territories could not be controlled and stabilized.

One of the widely applicable measures to improve the resilience of communities now and in the future is the implementation of green infrastructure (GI). Evolved to the level of strategy for capitalizing on natural advantages, GI combined with water-related infrastructure becomes green-blue infrastructure (GBI). Among the multiple definitions that GBI has enjoyed over time [24], the one issued by the European Union ensures a complete understanding of the term, by defining what GBI is, namely strategic planning, followed by the specification of spatial applicability at the national level, regional or local both in the countryside, but especially in the urban [13].

Located at the intersection of several disciplines, ecology and environmental protection, regional and urban planning, and engineering, GBI involves a complex of multifunctional ecosystems. Understanding the complex benefits of GBI allows for selecting the right option for sustainable territorial development throughout the business process life cycle. Research over time in the field of GBI has identified several representative gaps, which a DSS should be able to address. For example, GBI and DDS has been identified in [5] as a solution to rapid urbanization. The proposed DSS architecture solutions for GBI may face institutional and governance challenges such as unclear responsibilities, limited resources, and conflicting policies. Palla et al [36] argue that the involvement of all stakeholders such as residents and community groups in the maintenance of GBIs can improve the sustainability and resilience of GBIs. However, the authors note that stakeholder engagement is not fully integrated into the DSS for GBI. Salvia et al. [39], mention the lack of GBI implementation and maintenance, in which DSS can play an important role by providing information, especially for current maintenance and operation activities, which not only monitor change but also optimize and extend the lifetime of GBI. By integrating artificial intelligence (AI) and machine learning (ML) techniques for GBI decision support, this approach could help fill these gaps in comprehensive assessments of the benefits and costs of GBI interventions, as well as the role of institutional factors and governance in decision-making. To provide accurate and timely information, DSS can incorporate real-time information collected from various sources, such as sensors, remote sensing, social networks, and citizen science, for the efficiency of GBI updating and maintenance by facilitating interdisciplinary collaboration. By managing information on GBI performance and impact in real-time, DSS can provide policymakers and stakeholders with the necessary framework for tailored approaches to meet specific community needs. Data sources are important because their lack can lead to major challenges in using AI and ML for GBI decision-making. Without sufficient data, AI and ML models cannot predict the potential benefits and costs of GBI interventions. For example, the study by Li et al. [31] identifies the major problem in developing model-based AI models for predicting GBI effects on air quality in the absence of data on the spatial distribution of vegetation cover in urban areas. Another important aspect related to data is its quality and especially biases. They arose as a result of historical discrimination or unequal distributions of resources. Those used in training AI and ML models can raise potential problems because using AI and ML for decisions can lead to inaccurate predictions or perpetuate existing inequities. For example, Kang et al.[28] identify that the data used to train models based on satellite imagery tend to overestimate vegetation cover in wealthier neighborhoods and underestimate it in poorer neighborhoods, which may lead to an inequitable distribution of benefits resulting from GBI interventions. To these can be added according to the study carried out by Sun et. al [46, 47], the lack of transparency and limited accountability, which can lead to mistrust in the use of AI and ML models or a lack of understanding by stakeholders to assess the potential benefits and costs of different interventions. The study carried out by Fan [15], identifies the lack of inclusion of the context and requirements specific to each location. This information can help stakeholders maximize and extend the life of GBI by tailoring GBI implementation to specific locations, taking into account the specific context, and integrating existing infrastructure, while facilitating interdisciplinary collaboration between stakeholders, including institutional and governance factors in making decisions.

Overall, while DSS for GBI has shown promise in achieving multiple benefits, more research is needed to assess the effectiveness of different approaches and to understand the planning, social, cultural, economic, and financial dimensions of the decision-making process for the GBI. The proposed unified DSS platform includes these gaps 1/inter-institutional and multidisciplinary collaboration with the participation of all stakeholders, 2/optimization of work flows by including alongside monitoring practical operation and maintenance activities that ensure continuous updating through (re)configuration of GBI, 3 /identification of the basic layers for the implementation of a DSS, respectively the data sources, the manner of their processing at the level of technologies that ensure infrastructure and environmental monitoring, asset management, environmental monitoring, urban planning through geo AI modules, geo AI modules, adaptive AI, technologies , real-time data collection, analysis and decision-making, digital twin as a virtual reality in which simulations are carried out for the understanding or production of decisions and 4/ understanding the local context, and its specificity both for concrete proposals related to GBI implementation measures, but also for implementing DSS for GBI.

The methodology proposed for the development of the research had in mind the definition of the problem: the development of a DSS proposal for the GBI, in a comprehensive manner, which would address the main gaps identified by the lack of research in the field. The identification of these (relevant) gaps was made following the analysis of specialized literature, based on which 4 relevant gaps were selected that the DSS proposal deals with in the following. The methodology proposed for the implementation of DSS for GBI included two of the practical activities – operation and maintenance, with the greatest impact on GBI management and in covering the identified gaps. For each component selected to be part of the DSS, concrete examples were included with references that support the proposal highlighting the benefits resulting from the implementation of data components, technologies, AI-ML models for the management and decision-making of operation and maintenance of GBI, digital twin and applications for distributed DSS.

The article is structured in 7 sections as follows: section 1 presents an overview of the severity of urbanization and the resulting solution in response to climate change, namely the implementation of a DSS for GBI management, emphasizing its importance and highlighting the challenges faced by urban areas. The proposed methodology for the development of the research includes the selection of 4 relevant gaps with the highlighting of the limitations/challenges and detailing the way to overcome the limitations through the proposed DSS; section 2 identifies relevant approaches in GBI implementation, highlighting some examples of implementations in different countries and the benefits obtained through the ecosystem services generated. The gaps are selected and commented on, and solutions are proposed by including the missing components at the DSS level; section 3 presents in detail the analysis of the critical need for collaboration among all stakeholders for the successful implementation of GBI, addressing the interdisciplinary approach and cooperation among all stakeholders through DSS; section 4 details two of the most important business processes related to GBI management, operation and maintenance, as the core business processes by which they continuously update and maintain/(re)configure the GBI infrastructure. Concrete practical activities and modern tools proposed to make DSS for GBI appear are used as concrete examples of business flow for GBI management; section 5 presents the conceptual architecture of DSS for GBI and details the functional layers. Security aspects to prevent cyber attacks and ethical considerations arising from the use of AI and ML modules are also highlighted; section 6 details the criteria for measuring the success of DSS implementation for GBI and the implementation plan that can be followed by any public administration and community; section 7 includes the conclusions on the implementation of a DSS as a decision support and the activities related to the intelligent management of GBI as an urban public good through the implementation of the DSS. The section includes a summary of the main findings and recommendations for public administrations in the implementation and intelligent management of GBI, with the integration of existing infrastructure and by using modern tools proposed at the level of a DSS, and proposals for future research.

2 Relevant approaches in GBI implementation

Each country that adopted the GBI as a key strategy for sustainable development, took into account the local specifics and dimensions of territorial problems. The implementation of the GBI project could start from scratch, for large-scale, long-term projects as greenfield, or as brownfield for smaller-scale projects, based on existing infrastructure and quickly implemented in short terms. From the analysis of GBI implementations at the global level, it was observed that each approach was financially supported either by the central public administration in various formulas (policies, national funding programs or annually allocated subsidies), or by inviting investors interested in public-private partnerships with public administration. In many metropolitan cities around the globe, GBI climate change adaptation measures have emerged. For example, by implementing GBI, rainwater no longer overloads the sewer network but is collected, stored, conserved and used to irrigate green spaces and prevent flooding. Street trees, rain gardens, vegetated meshes, green roofs and green belts intercept, store and filter rainwater, store carbon, reduce pollution and urban heat stress and heat islands and reduce energy consumption, improving the built environment. Recreational facilities in urban parks provided by GBI stimulate physical activity and social interaction, improve health by helping to reduce deaths and hospitalizations, and strengthen the mental health of the population [29, 52]. Through GBI implementation, new industry insights and associated GBI services have been developed. For example, the production of GBI materials increases economic capacity by incorporating new technologies [20], reducing unemployment and generating new jobs or developing higher skills and new business opportunities [45]. Considering all of the above, green spaces contribute not only to increasing the economic value of properties but also to the quality of life of residents.

The ecosystem services generated by implementing GBI contrast with traditional approaches to implementing solutions based on grey infrastructures that generate unsustainable costs and urban degradation. If the financial benefits offered by GBI are compared with those offered by grey infrastructure to achieve similar effects, tangible and intangible savings or even additional income results are obtained, which ensure economic growth and sustainable urban development [7, 33]. Next, some relevant GBI implementation experiences in different areas of the world are presented.

Public administrations in Philadelphia and New York (USA) have implemented GBI projects that have become models for other cities. Through the approach supported by the government, their strategies and action plans include concrete terms and models of financial benefits, which highlighted the savings obtained from the implementation of the GBI, amounting to between 2 and 4 million euros, compared to the grey infrastructure implemented to solve some similar problems [33]

China has approached GBI implementation by adopting a government-level sustainable urban development strategy based on integrated spatial planning policies [17]. The implemented sponge city concept capitalizes on traditional Chinese green-blue methods. The implementation deadlines were set in the short term (until 2020) and long term (2050), each of which provided measurable objectives. GBI implementation included the benefits of improving ecological infrastructure and drainage systems for flood management (rain gardens, wetlands, ponds) through engineering methods managing 70-85of annual rainfall. The Sponge City government program includes 30 cities, with each pilot city being allocated a government subsidy for three years (with eligible activities for the purchase of raw materials, design and construction expenses). Each project was based on analyzes and assessments of local climatic and hydrological conditions, based on which annual investment values were estimated between USD 85 million for the provincial capitals and USD 57 million for smaller cities. Given the number of 30 cities and the relatively large budget, a possible long-term financing solution may be a public-private partnership.

The Dutch city of Rotterdam has addressed GBI as an urban resilience planning strategy and as a practical solution to the problems of sea level rise and flooding in extreme storms [17]. The suburb of New Castle Great Park in England proposed to resolve the fragmentation between new and traditional by implementing GBI corridors. Based on a strategic water surface management plan, the implementation of the GBI was initiated through local and regional partnerships [25, 34].

Detailed analyzes of the benefits of GBI systems compared to those obtained from the implementation of grey infrastructure, have been carried out both by GBI beneficiaries (local authorities, private institutions) and GBI providers (such as McDonald Mac Mot, but also many other public companies and private) or by associated academic researchers, each of them highlighting possible implementations with practical case studies [53], which can be an inspiration for cities that have not yet started such projects.

In all cases, through GBI implementation, environmental risks have been transformed into opportunities, and GBI has thus become a public good that directly contributes to sustainable urban development.

Comparisons between the two infrastructures, GBI and grey infrastructure, highlight the environmental, economic, and social benefits of multifunctional and sustainable GBI. However, by combining the two infrastructures, their long-term advantages are leveraged, particularly through the hydraulic control and storage components held by the grey infrastructure.

3 Interdisciplinary collaboration is the cornerstone of GBI projects

The complexity of implementing a GBI management project brings together in collaboration with all interested parties to achieve sustainable urban development and to increase the quality of life of citizens [49]. Each stakeholder actively participates in a win-win relationship with the public authority, depending on their collaborative role, possibly supported by modern information and communication technologies and methods [18, 19] and based on their financial contribution (co-financing).

Public administration has the role of regulation, control and administration. For this purpose, it analyzes and identifies territorial problems through specialized studies, and projects and evaluates and proposes investment strategies, plans and regulations.

During the implementation of the GBI, it continuously updates the legal and economic inventory of the public and private domain and monitors the indicators of the GBI project. It also establishes the maintenance work required by GBI management and authorizes work based on the regulations in force. Sometimes, carrying out these activities requires expertise and innovation from institutional partners outside the public administration. Thus, the public administration develops close collaborations with partners and independent technical specialists from the public or private professional environment that includes consultants with multiple skills, planners, architects, designers, builders, material producers and service providers from technical or financial consortia (investment funds or banks). Innovation is enhanced by developing partnerships with the educational and academic environment that provide the public administration with elements of research and knowledge transfer. Through citizen participatory processes, permit applications are published online and proposals/solutions are generated in the decision-making process for the good of the whole community, bringing together all stakeholders, economic agents, NGOs and citizens. Another important aspect of GBI implementation is a collaboration with funding groups, or GBI concessionaires interested in GBI's Return on Investment (ROI).

In Commission and European Union documents, the GBI is also perceived as a promoter of integrated spatial planning, which directly contributes to the development of land use plans and policies, the identification of multifunctional areas and habitat restoration measures [12, 14].

From the perspective of each category of partners, GBI brings benefits to each of them, fulfils both the strategic objectives of public administrations and private businesses, as well as the specific objectives of each partner and develops new services for citizens. Essential to the success of cooperation is the selection of partners, who are stimulated to collaborate through the benefits obtained.

4 GBI Operation and Maintenance

The interdisciplinary specificity of GBI and the need for collaborative decision-making with different partners combine the principles and structure of a multi-participant DSS, to support real-time decision-making [50], with multi-agent systems [23] and crowdsourcing [40, 51]. From the multitude of GBI management activities, those with a high degree of inter-institutional and public collaboration, respectively the operation and maintenance workflows through which the GBI is updated/(re)configured permanently have been selected to be addressed. Operational decisions at the DSS level are based on several main components:

- data sources: include the entire ecosystem of intelligent devices as a distributed physical layer in the field (IIoT, different types of sensors, controllers, robots, cobots, video cameras, drones, or other types of remote sensing devices). These devices allow data collection in real-time, and communicate the data in machine-to-machine (M2M) workflows that generate commands for other devices based on the data collected. The IIoT combined the Internet with wireless devices/sensors [32, 47] for adjusting the GBI operations. Typically data streams become very fast big data and include different formats. Including data stream in the DSS as soon as they are collected, increases the agility of operational or maintenance decisions, especially in a multi-user decision-making environment. Some data are big image files, collected before and after an operation, and integrated into the DSS by multi-agent systems. Other data have been integrated as data services for GBI monitoring. For example, IIoT sensors for water level measurement in rivers and lakes, air quality sensors, soil moisture sensors in parks and green spaces, or pressure sensors in pipelines can collect data and at the same time transmit commands to other devices e.g. intelligent valves for guiding the volume of water to storage tanks according to the amount of raining water falling per square meter

- technologies: by merging GIS, AI, and ML methodologies, among the technologies used within a DSS, the GeoAI platform underpins the DSS for GBI operation and maintenance in a multi-stakeholder collaborative environment. Cognitive modules and AI adaptive modules can improve GBI operation and maintenance decision-making processes by adapting to given changes and circumstances over time, for example:
  - Infrastructure Monitoring: The GeoAI platform may be used to continuously monitor the GBI infrastructure and spot possible issues before they become serious. To support preventative maintenance and efficient incident response, this information can be shared with numerous stakeholders, including maintenance teams, local government agencies, and emergency response organizations.
  - Asset Management: By offering real-time data on asset performance, utilization, and status, the GeoAI platform can assist GBI in managing its assets. To improve asset performance and cut downtime, this information can be shared with a variety of stakeholders, including asset managers and maintenance teams.
  - Environmental monitoring: By merging GIS, AI, and ML methodologies, the GeoAI platform may be used to monitor and evaluate environmental data linked to GBI. To support evidence-based decision-making and enhance environmental management practices, information on, for instance, air quality, water quality, and biodiversity can be shared with a variety of stakeholders, including environmental agencies and lawmakers.
  - Urban Planning: GBI can get help with urban planning via the GeoAI platform, which provides details on spatial data related to land use, transportation, and population demographics. This knowledge can be made available to a range of stakeholders, including taxpayers, urban planners, and policymakers, to assist sustainable and more just urban development. For example, in a city that has a network of pipes and other structures that help manage stormwater runoff, which includes sensors that collect data on water levels, flows, and other relevant factors, AI algorithms analyze this data to identify if there are problems potential or areas for improvement. Adaptive AI modules can be used to continuously refine and improve the DSS over time. If data reveals that certain areas of the stormwater network are consistently prone to blockages or overflows, AI algorithms could adjust the system's predictive models to better anticipate these problems and recommend appropriate maintenance or upgrade activities to operators. In addition, adaptive AI could also learn from the decisions and actions taken by human operators in response to DSS recommendations. If a maintenance crew decides to prioritize a specific GBI operation or maintenance activity, such as cleaning certain stormwater pipes based on DSS recommendations, and subsequent data shows that this action was effective in reducing bottlenecks, adaptive AI could use this information to improve its predictive models and recommendations for the future. Overall, the inclusion of adaptive AI modules in DSS for GBI maintenance and operations can help improve system accuracy and effectiveness over time through continuous learning based on data provided by data sources and based on human decisions. Different AI – tools based on advanced image analysis functionality and object-based classification capabilities for geospatial data, enable fast and accurate analysis of large amounts of remote sensing data such as aerial imagery and satellite imagery to achieve a) object-based image analysis: used to accurately identify and classify different features in the image, b) feature

extraction from geospatial data: for example, extracting vegetation and water bodies from satellite images, c) ML algorithms: for automatic feature classification in the image. AI algorithms can learn from user input to improve classification accuracy d) detect changes in the landscape over time by comparing two images taken at different times to identify changes in land use or the appearance of new features. Another example, human inspectors' capabilities are extended to automatic identification of GBI (species, health status, quality, etc.) with the help of AI tools using image-based species recognition functionality on mobile applications [41]. The ML algorithms (artificial neural network, probabilistic neural network, convolutional neural network, or other combinations of technologies [5]) assist field inspectors during the GBI inventory process. Better accuracy has been obtained when trained models use object datasets and libraries located geographically.

- digital twin: connecting the physical GBI infrastructure/world with their virtual replica in a DSS for GBI maintenance and operation, different scenarios can be simulated and the behavior of the GBI under different conditions can be predicted. This improves the decision-making and selection of maintenance activities. For example, in a city with a complex network of waterways and flood control systems, data from IIoT sensors placed throughout the network is used to simulate the effects of different weather conditions, water levels, and other factors on the system. This can help forecast potential network failures or inefficiencies and guide maintenance activities. In a multi-user environment, the digital twin can be accessed by various stakeholders such as city officials, engineers, and maintenance teams. Each stakeholder can use the digital twin to obtain information about various aspects of the system and make informed decisions about maintenance activities to be performed. City officials can use the digital twin to determine where to allocate resources for maintenance, while maintenance crews can use them to plan their activities more efficiently.

- distributed decision support layer: this layer includes applications for viewing GBI data and monitoring and performance metrics for real-time decision-making, controlling, and reporting GBI operation and maintenance. Using real-time multi-user DSS tools in a collaborative environment, stakeholders can work together to make informed decisions based on real-time data, improving overall GBI performance and user satisfaction. The different applications could be classified as follows:

  – dashboard-type applications: allow the real-time monitoring of features. Data science and data analytics engines over big data available for relevant periods, combined with real-time data reported after the completion of work enable, for example, action awareness, or estimation of the next maintenance work required. Difficult for humans to perform work orders that require material handling activities could be redirected automatically to be performed by cobots (collaborative robots) [11, 54]. Autonomous robots support human operators, through electro-mechanical structures in the case of co-manipulated robots, while retaining the human decision-making role. Collaborative bots programmed by non-experts are preferred for rapid deployments of GBI infrastructure

  – collaborative applications and web-based portal-type communication: allow online communication with citizens/economical agents, submission of their request for cutting vegetation, and transmissions the permits, answer to petitions or proposed project status, upon completion of the process

  – crowdsourcing application: bring citizens, NGOs, and government officials together to work toward greener cities. Understanding the target population and including all segments in the focus group is a best practice for obtaining better quality results. Crowdsourcing methods and experts included in the collaborative environment can help to avoid results distortions. Crowdsourcing is aided by platform accessibility and user experience [10].

The above components are just a few that could be included in DSS for GBI and are constantly moving forward from the technological point of view. Putting all components together, and integrating the existing infrastructure provides more savings and efficiencies for all partners throughout the entire GBI life cycle

5 Conceptual architecture of the GBI distributed decision support system

In the case of GBI, the large number of connected IIoT devices generate huge amounts of data, which pose a challenge in terms of storage volumes, high bandwidth consumption, latency in data processing, and privacy and security issues, especially in an open-to-the-public and multi-institutional framework. At the DSS technical level, GBI workflows require adequate computing and communication resources, and solutions for bottleneck problems in data latency and traffic congestion [30]. As a result, the proposed architecture will have to deal with congestion and delays The conceptual architecture will consider: 1) avoiding the deadlock that might have occurred as a result of huge volumes of data and requests from multiple IIoT systems and avoiding delays in responses. The proposed solution allows the execution of calculations as close as possible to the data sources, using edge computing and edge nodes, and data storage in the cloud; 2) real-time response, especially for situations where devices need to make decisions and act on their own. The ideal architecture for the GBI solution could be developed based on five logical layers that link 1) the distributed data source physical layer with different types of environmental sensors and actuators, 2) the communication layer – based on public and private networks, communication protocols and technologies such as 5G, LORA, SIGfox, NB-IIoT, wireless, Bluetooth, others, 3) data and storage model - cloud/edge/fog/sky computing, based on partners' infrastructure, 4) IIoT distributed tools and types of services – SaaS, PaaS, Iaas and 5) distributed level of decision support for monitoring, control, and reporting, as presented in [19]

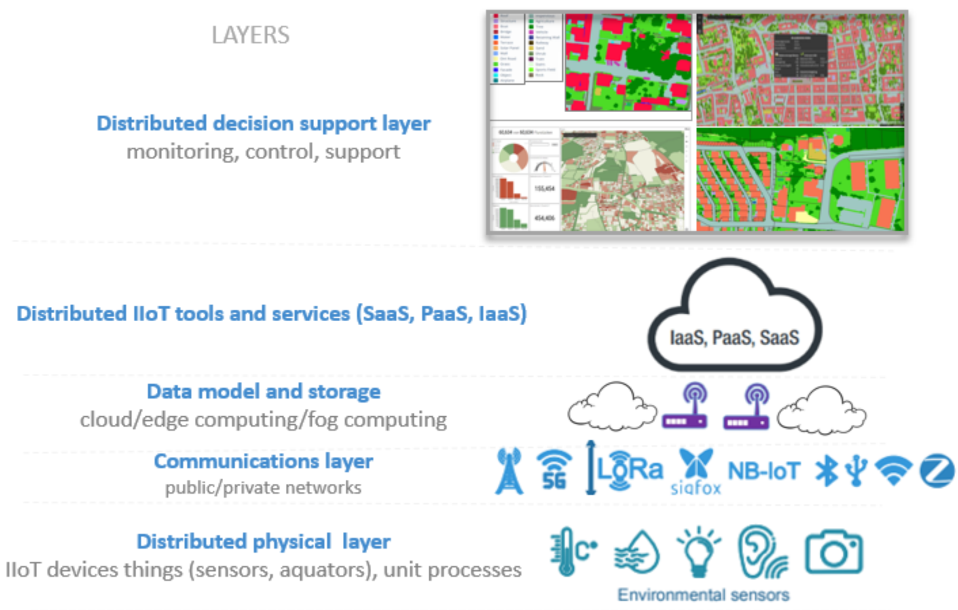

Figure 1: General description of the distributed architecture for CPS in the IIoT environment.Source: Adapted from [19]

The proposed architecture contributes to 1) low latency: by including fog and edge nodes; 2) geographical distribution throughout the administered territory: supported by fog computing that allows the distribution of services and applications in the network; 3) network heterogeneity: several types of communication capabilities for supporting different types of data processing; 4) interoperability: for supporting cooperation services between inter-institutional partners; 5) real-time interactions:

between fog computing applications; 6) scalability: increased adaptability by pooling resources. An improved architecture efficiency and scalability that develops deployment agility are sky computing [44] for multi-participant, multi-interaction environments and pay-as-you-go operating models when sky providers become partners in the collaborative environment. The architecture depends on 1) the number of partners involved in the project, 2) the development methodologies, and 3) the ICT products selected for implementation and the evaluation procedures [21]. Using several multi-criteria decision processes (MCDM), [16] describes a DSS for supporting the ICT selection of components for the multi-participant DSS for GBI. For more understanding, customized existing infrastructure that should be integrated, several architectures are detailed in [20] based on classification criteria to be used for ICT selection, and in [38] a multi-attribute method is proposed for the particular problem of cloud provider selection. Depending on the maturity of the market, there are still mixed environments with on-premises solutions combined with public and private cloud services. This allows the collection, cleaning, validation, structuring, and communication of edge, fog, or sky computing depending on the existing concrete situation, data feeds and computation that must flow through the network, the number of participants, and the activities performed by each participant within the DSS for GBI. The proposed architecture includes IIoT devices connected to the GBI infrastructure. Collected data can be classified and reused in various business processes [6] using a Big Data analytics module. To simulate and support finding solutions to complex decisions, multi-agent cooperation schemes, AI tools with object-oriented cognitive systems rely on deep learning algorithms. In the collaborative, virtual, shared environment, some multi-agents make decisions without the coordination of any central controller and exchange information with their pre-configured partners through the GBI communications infrastructure. The proposed solution supports the integration of several service-oriented cognitive systems [43] and multi-agent cooperative schemes and allows interactions with a wide variety of software sources owned by each participant. Agent-based modeling enables the development of an interconnected, flexible, and interoperable architecture of intelligent and autonomous digital twin agents. They interact in a structured framework that enables the efficient transfer of information and knowledge along the complex value chains of collaborative systems. Similar settings are used to control and operate robots, autonomous unmanned vehicles, mobile networks, and also sensor networks [54]. Regardless of the combination of IIoT and applications, the tools or services are linked together in a powerful solution through fog computing combined with edge computing and edge nodes for specific devices, distributing requests for providing cloud services to users, and solving latency limitations of processing [3]. As with any management solution in the past few years, digital twins have proven their great potential for intelligent decision-making. The full realization of this potential is still limited by both functional and, especially, non-functional constraints, which are related to the absence of a comprehensive framework for the development of architectures and the increasing complexity of real complex systems, emerging dynamics, and underlying interactions. Among the features analyzed, the strategy to improve the architecture will have to take into account the existing infrastructure by selecting the right environments for the configuration of fog, edge, mobile, and sky computing tasks and allow dynamic relocation, considering the communication interface that determines the node location using robust and adaptive algorithms. Also, the collaboration between nodes by using a load balancing algorithm to reduce the processing of low- and high-priority data, while fog computing servers fulfill tasks with redundant systems will be a priority for the decision about the final architecture.

5.1 Security and ethical issues

In the contemporary digital era, security and ethical concerns are important factors in designing and implementing DSS. The following are the primary factors used to address these challenges:

- data security and privacy: Data security and privacy concerns are brought up since distributed DSS relies on collecting, analyzing, and transferring data from various sources. Two potential measures that could help maintain the data's integrity and confidentiality, prevent data and infrastructure vulnerabilities, and protect data from assaults are access control and encryption. Owing to the rapid development and variety of IIoT devices, decentralized systems, third-party contractor access, inconsistent segmentation for various connections, and network dead spots should all be considered vulnerability protection considerations. Given that GBI decision-making participants may be spread out and possibly at a distance from one another, as well as the possibility that they may use mobile devices for data collection, reporting, and other purposes, biometric methods and tools [1, 35] can be used for authentication and access for secure collaboration. A security analysis of communications and ongoing monitoring of transmission and processing delays are required to prevent cyber security incidents and to boost security. Security standards can be utilized in this context - ISO 27001 for operationally mature enterprises and NIST SP 800-53 for organizations that are just starting to create a risk management strategy [37]. Furthermore, ethical considerations must be made to ensure that data is collected, processed, and shared legally and openly

- cybersecurity threats: distributed DSS is susceptible to several online dangers, including malware, denial-of-service assaults, and hacking. To stop and lessen the effects of such attacks, it is crucial to have cybersecurity measures in place, such as firewalls and intrusion detection and response systems. In addition, to prevent DSS from harming people or organizations, ethical issues must also be taken into account
- bias and discrimination: If the data used to train the AI components is biased, distributed DSS may produce discriminatory results due to inherent or introduced biases. To prevent and mitigate the effects of bias and discrimination, ethical principles such as transparency, neutrality, and openness must be incorporated into the design and development of DSS. Decision-making processes must also be routinely monitored and audited to detect and correct any potential biases
- specialists' professional ethics: collaborative interactions between individuals, organizations, and the public are still understudied, but we must consider their negative consequences for individuals and society. From this perspective, adequate guarantees must be included at the international level. Data protection standards facilitate their use and storage to avoid infringing on citizens' rights and hurting holders (the public)

Because of the DSS architecture's complexity and uniqueness, there are constant worries about security, as well as moral and humanitarian considerations to address any ethical and security threats. Additionally, it necessitates ongoing professional growth in conjunction with advancements in technology, judicial guidelines, and global norms about fundamental principles and human rights.

6 Implementation plan

6.1 Success criteria

The DSS implementation is a smart project that necessitates the use of smart project management implementation practices. Based on a quantitative correlational study [2] of various European Smart City projects, the conceptual framework outlines a holistic view of four management functions: Smart Planning, Smart Organizing, Smart Leading, and Smart Controlling practices all contribute to project success. Recommended steps for implementation The recommended steps for implementing a DSS for GBI are crucial to ensure the success of the project. The following stages can be used as a guide for the implementation process:

6.2 Recommended steps for implementation

The recommended steps for implementing a DSS for GBI are crucial to ensure the success of the project. The following stages can be used as a guide for the implementation process:

- *Political Actions*: establishing political actions (global, continental, national, and regional/local) involves promoting the concept of GBI and gaining support from policymakers, politicians, and other relevant stakeholders.

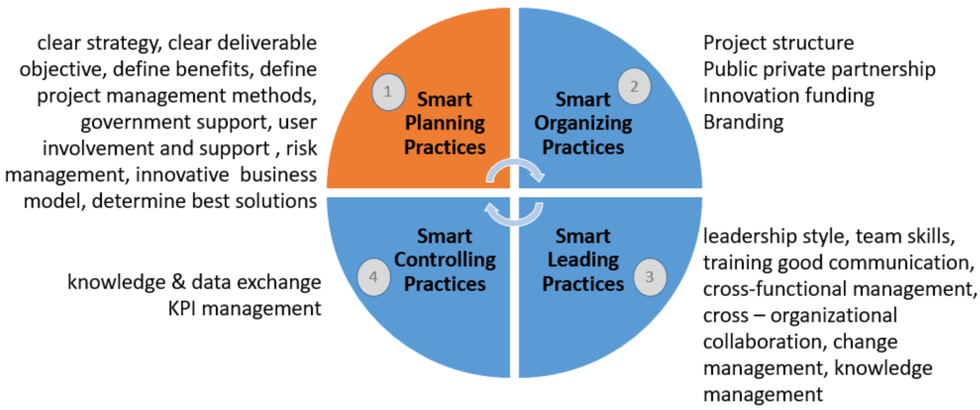

Figure 2: Conceptual frameworks of smart project management practices and success. Source: Adapted from [2]

- *Clear Vision and Objectives*: a clear vision and measurable objectives should be established at the level of strategy and national legislation. This will ensure that the project is aligned with the goals of the organization and the progress can be measured effectively.
- *Potential Sources of Financing*: this is essential for the successful implementation of the project and includes negotiating terms with potential financiers and ensuring that funding is available throughout the project's duration.
- *Action Plan*: this is critical for the successful implementation of the project and includes eligible category activities and specific monitored indicators to track progress and ensure that the project is on track.
- *Collaboration Partners*: this is essential to ensure that the project is successful and involves identifying and engaging with relevant stakeholders and highlighting the benefits for each participating party.
- *GBI Implementation*: this is a core component of the project and includes designing, constructing, operating, and maintaining the infrastructure.
- *Infrastructure Operating Platforms*: this is crucial for ensuring cooperation and participative communication in the virtual environment of all those interested in roles and responsibilities.
- *Dissemination of Good Practices*: this is essential for ensuring that the project's outcomes are widely shared and progress encountered.
- *Loading Knowledge Platforms*: with the results obtained, evaluations, and comparisons between the costs of GBI versus grey infrastructure become essential to create best practices in the field.
- *Implementation of Cyber Security Tools*: is crucial to ensure that the project's data and information are secure and protected from cyber threats.
- *Monitoring Ethical Aspects*: this is essential to ensure that the project is aligned with ethical standards and principles.
- *Plan for Managing the Impact*: generated by human resource retraining programs to support the operation of newly implemented technologies is crucial for ensuring that the project's outcomes are sustainable and that the impact on the workforce is managed effectively [42].

7 Conclusions

DSS for GBI is a solution to climate challenges, with multiple other benefits resulting from collaboration and for the benefit of all stakeholders. The transformative change derived mostly from the implementation of a multi-participant distributed DSS generates GBI management with integrated strategic objectives at the level of the various participating organizations - public administration, economic agents, and civil society. Although the adoption of automation is intended for human well-being [22], the masking of inefficiencies and the rigidity of processes does not lead to the success of DSS implementation for GBI. Furthermore, they are not resolved solely by faster processes. Throughout this regard, successful implementation entailed the alignment of all participants to a common IT vision, the identification of business perspectives, and the rethinking of all business processes. Only after this alignment would the multi-participatory system be able to move on to process automation and the provision of personality tools to all participants for the activity performed, possibly through the integration and modernization of existing ones, to gain more business value and benefits. In this sense, the addition of disruptive technologies and the emergence of new professions open up new industrial and service opportunities. The proposal to implement a DSS for GBI, as a collaborative decision-making tool that supports two fundamental practical activities for GBI change management, namely GBI operation and maintenance, reflects the research's innovative contribution. Combining the practical nature of GBI change management and the collaboration of all interested parties, based on roles and responsibilities, can help not only public authorities to implement the GBI activities comprehensively in the first phase, but also cheaper, by bringing into partnership all those interested, as contributors or consumers of information and decision-making. As a result, decision-making has a solid basis and takes into account the context of all those who act on the same territory for the same infrastructure's maintenance. The inclusion of the four key elements, identified as gaps in previous research, led to the following results:

1. interdisciplinary collaboration among all stakeholders: collaborative and multi-user participation involves stakeholders in the decision-making process, resulting in a more precise representation of various perspectives and needs. Practical experience has demonstrated that the involvement of multiple interested parties in the process

    - increases the effectiveness of the DSS by answering the needs of all stakeholders
    - improves the ability to solve problems by pooling resources (data sources, infrastructure on the same territory, AI models, and the expertise of those involved)
    - improves the ability to solve problems by pooling resources (data sources, infrastructure on the same territory, AI models, and the expertise of those involved)
    - improves the transparency and legitimacy of the decision-making process and implicitly takes responsibility
    - increasing the efficiency and effectiveness of the decision-making process by bringing together diverse expertise and knowledge, which allows for decision-making to be simplified and better decisions to be made in less time. Multi-stakeholder participation facilitates the integration of various perspectives and areas of knowledge, leading to improved decision-making outcomes

2. The inclusion of the two practical activities of operation and maintenance, with the detailing of the components by activity, the indication of possible solutions, and the highlighting of the benefits obtained, improves understanding of the approach and opens up new perspectives for those interested in implementing DSS for GBI

3. detailing the main technological components of the DSS for GBI, with examples of practical use cases, brings technology closer to users at the Smart City level, making the solution more attractive to both central and local administrations.

4. Taking into account the territory's context and conditions provides optimum utilization of existing resources, a better understanding of the local context, constraints, and better integration at the level of the proposed DSS architecture.

The 5-layer architecture concept exposition provides an excellent framework for identifying institutional partners who can directly contribute to DSS implementation. The proposed DSS framework, which is based on a solution, empowers interdisciplinary teams by providing new insights that foster innovation. By incorporating new technologies such as Sky, AI tools, big data and analytics, edge computing, cloud, and mobile, IIoT and biometric system tools, cobots, and digital clones alongside humans, complex issues have been addressed, and GBI management workflows have been improved. The proposed DSS for GBI increases decision-making capacity and can serve as a foundation for the implementation of similar systems by governments and local communities to build sustainable and resilient communities.

Moreover, the modularization of the proposed solution ensures its scalability to other activities carried out on the same territory, contributing to the development of a sustainable future. Concerns about incorporating AI models in DSS for GBI with a strong ethical framework and a focus on promoting equitable and sustainable outcomes are addressed in the article, and the conclusions are supported by previous researchers [27]. The paper confirms the ethical component of AI in DSS for the GBI and emphasizes the need for transparency about how the AI module makes decisions in hopes of preventing reinforcing or amplifying biases or inequalities. As sensitive topics, the research also includes data privacy and cyber security. The technology is widely available globally, and the methods are simple to replicate and adapt, making them suitable for testing and scaling in other contexts.

Future research on GBI decision architectures should concentrate on improving data availability and quality, developing more robust and transparent AI models for use in diagnostics, forecasting, and prediction, and engaging stakeholders in a more inclusive and participatory manner. Furthermore, DSS decision architectures for GBI should consider the larger institutional and governance context in which they operate, such as the need for clear policy frameworks, adequate funding, and effective coordination among various stakeholders.

Finally, GBI DSS architectures should be evaluated based on their efficiency, effectiveness, and equity in achieving GBI goals like improving ecosystem services and promoting social inclusion.

Beyond the legislative and environmental policy barriers that can inhibit the successful implementation of a DSS for GBI, the article considers lessons learned from global implementation experiences along with research and successful implementations to date, proposing management criteria for the successful implementation of such a project and an implementation plan.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Aftab, A.;Khan, F.A.; Khan, M.K., Abbas, H.; Iqbal, W; Riaz, F. (2021).Hand-based multi-biometric systems: state-of-the-art and future challenges. PeerJ Computer Science 7:e707. https://doi.org/10.7717/peerj-cs.707, 2021.

[2] Alshahadeh, T. (2018). Smart Cities, Smarter Management: developing a Smart framework for smart city projects, Management in Europe, Aydin University, Istanbul, Turkey GE-International Journal of Management Research ISSN (O): (2321-1709), ISSN (P): (2394-4226), Volume 6, Issue 9, September 2018, 2018. Accessed on March 10.03.2023.

[3] Avasalcai, C.; Murturi, I.; Dustdar, S. (2020). Edge and fog: A survey, use cases, and future challenges. Fog Computing: Theory and Practice, Wiley, pp.43-65, doi: 10.1002/9781119551713.ch2, 2020.

[4] Azlah, M.A.F.; Chua, L.S.; Rahmad, F.R.; Abdullah, F.I.; Wan Alwi, S.R. (2019). Review on Techniques for Plant Leaf Classification and Recognition. Computers 2019, 8, 77. https://doi.org/10.3390/computers8040077, 2019.

[5] Brom P., et. all (2023). A Decision Support Tool for Green Infrastructure Planning in the Face of Rapid Urbanization. Land. 2023; 12(2):415. https://doi.org/10.3390/land1202041, 2023.

[6] Candea C., Filip F.G. (2016).Towards Intelligent Collaborative Decision Support Platforms, Studies in Informatics and Control, ISSN 1220-1766, vol. 25(2), pp. 143-152. https://doi.org/10.24846/v25i2y201601, 2016.

[7] Chamoso, P., González-Briones, A., De La Prieta, F., Venyagamoorthy, G.K. and Corchado, J.M. (2020) Smart city as a distributed platform: Toward a system for citizen-oriented management. Computer communications, 152, pp.323-332 (2020). Accessed on March 10.03.2023.

[8] Choi, C., Berry, P., Smith A. (2021).The climate benefits, co-benefits, and trade-offs of green infrastructure: A systematic literature review. J Environ Manage. 2021 Aug 1;291:112583. doi: 10.1016/j.jenvman.2021.112583, 2021.

[9] [online] Development of the world population from 1950 to 2050 (in billions). Statista 2023, Available: https://www.statista.com/statistics/262875/development-of-the-world-population/, Accessed on March 09.03.2023.

[10] Diop, E.B.; Chenal, J.; Tekouabou, S.C.K.; Azmi, R. (2022). Crowdsourcing Public Engagement for Urban Planning in the Global South: Methods, Challenges and Suggestions for Future Research. Sustainability 2022, 14, 11461. https://doi.org/10.3390/su141

[11] El Zaatari, S., Marei, M., Li, W., Usman, Z. (2019). Cobot programming for collaborative industrial tasks: An overview, Robotics and Autonomous Systems, Volume 116, 2019, Pages 162-180, https://doi.org/10.1016/j.robot.2019.03.003.2019.

[12] [online] European Commission (EC). Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions. Green Infrastructure (GI)—Enhancing Europe's Natural Capital. COM(2013) 249 Final, Accessed on March 10.03.2023.

[13] [online] European Commission (EC).The Multifunctionality of Green Infrastructure. Science for Environmental Policy. In-Depth Reports, March 2012, Available: https://ec.europa.eu/environment/nature/ecosystems/docs/Green_Infrastructure.pdf. Accessed on March 10.0

[14] [online] European Commission (EC). Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions. Green Infrastructure (GI)—Enhancing Europe's Natural Capital. COM(2013) 249 Final. Accessed on March 10.03.2023.

[15] Fan, X., Wei, H., Zhang, Q., Wang, Y. (2021). Smart decision-making system for green-blue infrastructure planning and management. Environmental Science and Pollution Research, 28(2), 1474-1484, 2021.

[16] Farshidi, S., Jansen, S., de Jong, R., Brinkkemper, S. (2018). A decision support system for software technology selection, Journal of Decision Systems, 27:sup1, 98-110, DOI: 10.1080/12460125.2018.1464821 (Access at A decision support system for software technology selection (tandfonline.com)).

[17] Feiran, L., Jianfeng, Z. (2022). A review of the progress in Chinese Sponge City programme: challenges and opportunities for urban stormwater management. Water Supply 1 February 2022; 22 (2): 1638–1651. doi: https://doi.org/10.2166/ws.2021.32, 2022.

[18] Filip, F.G. Collaborative decision-making: concepts and supporting information and communication technology tools and systems. International Journal of Computers Communications and Control 17(2). https://doi.org/10.15837/ijccc.2022.2.4732, 2021.

[19] Filip, F.G., Leiviska, K. (2023). Infrastructure and Complex Systems Automation. In: Nof S Y (ed.) Handbook-of-Automation, 2023. Second edition, Springer, ISBN: 9783030967284. Accessed on March Accessed on March 10.03.2023.

[20] Filip, F.G., Zamfirescu, C.B., Ciurea, C.: (2017). Computer-Supported Collaborative Decision-Making. Springer, Cham. Accessed on March 10.03.2023.

[21] Filip, F.G. (2012).A decision-making perspective for designing and building information systems. Int. J. Comput. Commun. 7(2), 264–272, 2012. Accessed on March 10.03.2023.

[22] Filip. F.G. (2021). Automation and computers and their contribution to human well-being and resilience. Studies in Informatics and Control 30(4), 5-18 https://doi.org/10.24846/v30i4y202101, 2021.

[23] Frank L., et.al (2016). Cooperative Control of Multi-Agent Systems, ISBN: 1447171942, Springer London Ltd. 2016. Accessed on March 10.03.2023.

[24] [24] Grabowski, Z.J. et al (2022). What is green infrastructure? A study of definitions in US city planning. Frontiers in Ecology and the Environment, 20(3), pp.152-160. https://doi.org/10.1002/fee.2, 2445, 2022.

[25] Hamann, F., Blecken, G.-T., Ashley, R. M., Viklander, M. (2023). Valuing the Multiple Benefits of Blue-Green Infrastructure for a Swedish Case Study: Contrasting the Economic Assessment Tools B£ST and TEEB. Journal of Sustainable Water in the Built, 2023.

[26] Hassan, R. et. al, (2022). Green Infrastructure: Materials and Applications, Springer Nature Singapore Pte Ltd. 2022. https://doi.org/10.1007/978, 2022.

[27] Jobin, A., Ienca, M., Vayena, E. (2019).The global landscape of ethics guidelines. AI. Nature Machine Intelligence, 1(9), 389-399), 2019.

[28] Kang, D., Yu, J., Choi, J. (2021). Biases in satellite-based vegetation indices and their impacts on machine learning prediction of green infrastructure distribution in urban areas. Landscape and Urban Planning, 213, 103999, 2021.

[29] Kim, D., Song, S.K. (2019) The Multifunctional Benefits of Green Infrastructure in Community Development: An Analytical Review Based on 447 Cases. Sustainability 2019, 11, 3917, 2019. Accessed: https://www.mdpi.com/2071-1050/11/14/3917

[30] Li, G., Wu, J., Li, J., Wang, K., Ye, T. (2018). Service Popularity-Based Smart Resources Partitioning for Fog Computing-Enabled Industrial Internet of Things, IEEE Transactions on Industrial Informatics, vol. 14, no. 10, pp. 4702-4711, Oct. 2018, do

[31] Li, M., Zhang, J., Li, Y., Li, W. (2020). An analysis of the research progress and prospects of urban air quality research based on artificial intelligence. Journal of Cleaner Production, 257, 120553, 2020.

[32] Marjani, M. et al.(2017). Big IoT Data Analytics: Architecture, Opportunities, and Open Research Challenges, IEEE Access, vol. 5, pp. 5247-5261, doi: 10.1109/ACCESS.2017.2689040 (Access at: https://ieeexplore.ieee.org/document/7888916), 2017.

[33] O'Donnell, E.C.; Netusil, N.R.; Chan, F.K.S.; Dolman, N.J.; Gosling, S.N. (2021). International Perceptions of Urban Blue-Green Infrastructure: A Comparison across Four Cities. Water 2021, 13, 544. https://doi.org/10.3390/w13040544, 2021.

[34] O'Donnell, E., Woodhouse, R., Thorne, C. (2018). Evaluating the multiple benefits of a Newcastle SuDS scheme. Proc. Inst. Civ. Eng. Water Manag. 2018, 171, 191–2026, 2018. Accessed on March 10.03.2023.

[35] Özbek, N.S. (2020). Co-Design Approach and Co-Simulation Tools for Networked Cyber-Physical Control Systems, November 2020, DOI:10.1109/3ICT51146.2020.9311967, (2020) International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICt), 2020.

[36] Palla, A., Pagliaro, G., Lafortezza, R. (2021). Community-based maintenance of green infrastructure: An exploratory study. Journal of Environmental Management, 297, 113338, 2021.

[37] [online] Percentage of population living in urban areas worldwide from 1950 to 2050, by regional development. Statista 2023, Available: https://www.statista.com/statistics/671366/change-in-urbanization-of-countries-worldwide-by-regional, 2023. Accessed on March 10.03.2023.

[38] Rădulescu, C.Z., Rădulescu, I. (2017). An extended TOPSIS approach for ranking cloud service providers. Stud. Inform. Control. 26(2), 183–192, 2017. Accessed on March 10.03.202.

[39] Salvia, M., Fernández, M., Paruelo, J. M., Oesterheld, M. (2021). Data-driven decision-making for green infrastructure management in cities. Science of the Total Environment, 751, 141804, 2021.

[40] Schrammeijer, E.A., van Zanten, B.T., Verburg, P.H. (2021). Whose park? Crowdsourcing citizen's urban green space preferences to inform needs-based management decisions, Sustainable Cities and Society, Volume 74, 103249, 2021.

[41] Schneider, S., Greenberg, S., Taylor, G.W., Kremer, S.C. (2020). Three critical factors affecting automated image species recognition performance for camera traps, 07 March 2020. https://doi.org/10.1002/ece3.6147, 2020.

[42] Seidl, R., Tisdell, J. G. (2021).Decision support systems in sustainable water management: a review of current applications and future directions. Sustainability,

[43] Spohrer, J., Maglio, P.P., Vargo, S.L., Varg, M. (2022). Service in the AI Era; Science, Logic, and Architecture Perspective, Business Experts Press LLS, ISBN-13: 978-1-63742-304-2, 2022.

[44] Stoica, I., Shenker, S., (2021).From Cloud Computing to Sky Computing. In Workshop on Hot Topics in Operating Systems (HotOS '21), May 31-June 2, 2021, Ann Arbor, MI, USA. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3458336.3465302, 2021.

[45] Sturiale, L., Scuderi A. (2019).The Role of Green Infrastructures in Urban Planning for Climate Change Adaptation. Climate. 2019; 7(10):119. https://doi.org/10.3390/cli7100119, 2019.

[46] Sun, C., Puig, V., Cembrano, G. (2020). Real-Time Control of Urban Water Cycle under Cyber-Physical Systems Framework. Water 2020, 12, 406. https://doi.org/10.3390/w12020406, 2020.

[47] Sun, X., Zhang, Y., Zhang, C. (2021). The potential role of artificial intelligence in green infrastructure planning: Evidence from a case study in Shenzhen, China. Land Use Policy, 108, 105459, 2021.

[48] Van Oijstaeijen, W., Van Passel, S, Cools,J. (2020). Urban green infrastructure: A review on valuation toolkits from an urban planning perspective, Journal of Environmental Management, Volume 267,2020,110603, https://doi.org/10.1016/j.jenvman.2020.110603, 2020.

[49] Venkataramanan, V., Lopez, D., McCuskey, D.J., Kiefus, D., McDonald, R.I., Miller, W.M., Packman, A.I., Young, S.R. (2020). Knowledge, attitudes, intentions, and behaviour related to green infrastructure for flood management: A systematic literature review, Science of The Total Environment, Volume 720, 137606, https://doi.org/10.1016/j.scitotenv.2020.137606, 2020.

[50] Visan, M. (2019). Spatial and territorial development planning: digital challenge and reinvention using a multi-disciplinary approach to support collaborative work, 7th International Conference on Information Technology and Quantitative Management (ITQM 2019), Procedia Computer Science, 162, 795-802, 2019. Accessed on March 10.03.2023.

[51] Wang, Y., Gao, S., Li, N., Yu, S. (2021). Crowdsourcing the perceived urban built environment via social media: The case of underutilized land, Advanced Engineering Informatics, Volume 50,2021,101371, ISSN 1474-0346, https://doi.org/10.1016/j.aei.2021.101371, 2021.

[52] Wilbers, G.J., de Bruin, K., Seifert-Dähnn, I., Lekkerkerk, W., Li, H., Budding-Polo Ballinas, M. (2022). Investing in Urban Blue–Green Infrastructure—Assessing the Costs and Benefits of Stormwater Management in a Peri-Urban Catchment in Oslo, Norway. Sustainability 2022, 14, 1934, 2022. Accessed: https://www.mdpi.com/2071-1050/14/3/1934.

[53] Xu, C. et. al. (2021). Environmental and economic benefit comparison between coupled grey-green infrastructure system and traditional grey one through a life cycle perspective, Resources, Conservation and Recycling. vol. 174, p.105804. https://doi.org/10.1016/j.resconrec.2021.105804, 2021.

[54] Zhang, K., Yang, Z., Başar, T. (2021). Decentralized multi-agent reinforcement learning with networked agents: recent advances. Front Inform Technol Electron Eng 22, 802–814, 2021. https://doi.org/10.1631/FITEE.1900661, 2021.

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