18(1s), Spring 2026

Journal of Animal Environment
(E-ISSN 2717-1396, ISSN 2717-1388)
Journal homepage: http://www.aejournal.ir

Original Research Paper

# Animal-Centered Urban Planning Frameworks for Improving Human-Wildlife Coexistence in Smart Cities

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**Abstract:** Urbanization, especially rapid urbanization, has brought new problems of habitat fragmentation and increased human–wildlife interaction which poses ecological, environmental and socio-economic challenges to the modern smart cities. Traditional planning processes tend to focus on infrastructure and economic development while paying little attention to conservation of biodiversity and wildlife habitat needs, and can ultimately lead to a loss of ecological connectivity and increasing human–wildlife conflict. To foster sustainable human-wildlife coexistence, this study suggests an Animal-Centered Urban Planning Framework that brings together the Internet of Things (IoT), Artificial Intelligence (AI), Geographic Information Systems (GIS), remote sensing, digital twins and participatory governance. The framework will comprise several functional layers, such as data collection, monitoring of wildlife, AI-based spatial analysis, conflict prediction and policy integration, allowing for real-time assessment of ecosystems and data-driven informed urban planning. Ecological, environmental and technological indicators include biodiversity conservation, habitat connectivity, conflict reduction, decision-support capability and sustainability performance, whilst social indicators include sustainability performance. Comparative analysis shows that the proposed framework delivers significantly better performance compared to conventional urban planning, with 91% of biodiversity conserved, 89% of the habitat connected, 90% of reduction of human–wildlife conflict, 95% of intelligent decision support capability, and 94% of the overall sustainability performance. The results show that the combination of ecological intelligence and smart city technologies has a great effect on increasing biodiversity management in urban areas and decreasing ecological risks. The proposed framework offers a flexible and scalable approach to building smart cities, resilient, and inclusive to wildlife in accordance with global sustainability objectives.

**Keywords:** Animal-centered urban planning, smart cities, human–wildlife coexistence, biodiversity conservation, Internet of Things (IoT), artificial intelligence, GIS, digital twins, ecological connectivity, sustainable urban development.

## I. Introduction

The rapid urbanization has led to the complex and dynamic relationship between the human systems and the natural systems within cities. Worldwide, more than 50% of the world's population now lives in cities, and this trend is projected to increase in the next few decades. The development of transport networks, housing estates, commercial areas and industrial estates has significantly modified landscapes, which were previously teeming with wildlife. The loss of natural areas and their replacement by human-made landscapes push many animal species into adapting to the urban environment, such as many birds, mammals, reptiles, amphibians, insects, and pollinators. Some species are able to make use of urban resources, others suffer from loss of habitats, decrease in their mobility, population size and mortality. Cities are now important ecosystems for the conservation of biodiversity and the development of urban areas needs to be tackled at the same time. The idea of

***Corresponding Author:**
Received: 24th April, 2026; Revised: 11th May, 2026; Accepted: 24th May, 2026; Available Online: 6th June, 2026
(DOI): 10.70102/AEJ.2026.18.1s.70

"wildlife-inclusive cities" has thus become more popular as a concept that can be used to integrate ecological conservation into urban planning without compromising the human population or the welfare of wildlife [1].

The increasing role of human–wildlife interactions in contemporary urban environment is illustrated by recent real world examples. Peri-urban regions are seeing large mammals like deer, wild boars, foxes, monkeys, elephants arbitrarily enter urban areas seeking food and shelter, while even leopards are not far behind in certain fast-growing suburbs of metropolitan areas. At the same time, urban populations of birds, bats, pollinators and small mammals have unique ecological functions that maintain ecosystem resilience, pest control, pollination and seed dispersal. But, these interactions can result in conflicts such as road traffic accidents, damage to property, disease transmission issues, human safety and animal welfare hazards. Climate change exacerbates these problems by changing species distribution, changing migration routes and making more and more use of urban green space as a climate refuge. Therefore researchers have stressed that besides wildlife conservation, the issues of shared responsibility, adaptive governance and mutual recognition of human and animal interests in urban settings are key for effective co-existence [2, 4].

The new concept of "smart city" is bringing together new digital technologies that offer unprecedented opportunities for making use of advanced technologies and digital systems in sustainable urban planning. Internet of Things (IoT) devices, artificial intelligence (AI), geographic information systems (GIS), remote sensing, cloud computing, digital twins, and real-time sensing infrastructures can serve to enhance transportation, environmental monitoring, energy management, and public services in smart cities. However, in spite of these developments, the traditional approach to urban planning has still been mostly human-centred, with a focus on the needs of people with regard to transportation, housing, economic development and infrastructure, and relatively less on the ecological needs of wildlife. This has led to many smart city projects focusing on technological efficiency, but not taking into account the principles of biodiversity conservation and animal-centred planning in decision-making processes. Recent research promotes the concept of a smart city that becomes a nature-positive city by combining the ecological intelligence with digital innovations to create sustainable urban development [5], [6].

While great advances have been made in urban ecology, biodiversity monitoring, environmental modelling and smart city technologies, there are important gaps in research. Studies, however, are often conducted on wildlife conservation, urban planning, environmental sensing or smart city technologies separately and do not combine them in a common planning approach. Much of the urban planning strategies still rely on static evaluation of land use and periodic ecological surveys which may not be adequate to address the rapidly evolving urban ecosystem. Likewise, wildlife monitoring programs often monitor the presence of species, but do not explicitly inform planning decisions that involve connecting habitat, providing green infrastructure, transportation systems, or policy adoption. Additionally, there has been little focus on predicting human–wildlife conflict events with AI-powered spatial analysis and on-the-spot environmental information. Current urban biodiversity management practices are constrained by the lack of comprehensive frameworks that integrate ecological sustainability, technological intelligence, urban governance and citizen participation, which are all equally relevant for the preservation and enhancement of urban biodiversity [1, 4].

Current methods of urban wildlife management have a number of drawbacks. The traditional ecological surveys are labor intensive, time intensive, geographically limited, and generally don't record temporal dynamics of animal movements. Habitat mapping using Geographic Information System (GIS) technology can give useful spatial data, but is usually not flexible and intelligent enough to adapt in real time. The ability of remote sensing technologies to monitor changes in land cover is effective, but is less useful at finer spatial scales for understanding species behaviour and use of habitat. Wildlife recognition systems using AI show high detection accuracy, but are often used in stand-alone monitoring systems, without being incorporated into wider urban planning processes. Likewise, citizen science platforms provide useful biodiversity observations but reporting quality is variable, spatial data is not fully available, and data is not homogenous, limiting the usefulness of these data for broad-scale planning applications. The current smart city platforms focus mainly on optimizing human mobility, traffic, energy efficiency and public services and ignore the wildlife movement corridors, connectivity and habitat conservation needs. Therefore, current coexistence between human and wildlife is still hindered by lack of integration of policies, lack of interoperability between technologies and fragmented data sources in rapidly urbanizing environments, [2], [5] and [6].

To overcome these challenges, a new paradigm for urban planning is needed, one that has a holistic, interdisciplinary and animal-centered approach that incorporates ecological science, digital technologies, environmental monitoring, spatial intelligence, governance mechanisms and

community engagement in a holistic decision-support framework. This should involve ongoing monitoring of the environment and wildlife and involve AI-based spatial modelling to establish an understanding of habitat conditions, to forecast potential conflicts, to guide adaptive urban planning decisions, and to monitor ecological performance based on measurable indicators of sustainability. Incorporating biodiversity into the planning of smart cities will not only contribute to the preservation of biodiversity populations, but also lead to better ecosystem services, climate resiliency, environmental quality, and cities' livability. An interdisciplinary approach bringing together ecological, technological and social aspects is gaining acceptance as a crucial strategy to realize long-term human–wildlife coexistence in urban landscapes [4], [6].

The present paper introduces an Animal-Centered Urban Planning Framework for Improving Human–Wildlife Coexistence in Smart Cities (HWCSC), which establishes a planning framework that combines advanced sensing technologies, wildlife monitoring using AI, spatial analysis by GIS, ecological connectivity assessment, and evidence-based policy support. The proposed framework will enable informed decision making, through continuous environmental monitoring, intelligent habitat assessment, predictive analysis of conflict and adaptive governance strategies that will benefit both humans and urban wildlife.

The main goals of this study are: (i) to explore ecological and technological principles of animal-centred urban planning; (ii) to study the use of smart city technologies for wildlife conservation, such as IoT, artificial intelligence, GIS, remote sensing and digital twins; (iii) to identify eco-, environmental, and socio-economic indicators for the assessment of human-wildlife coexistence; (iv) to create the multi-layer integrated framework for wildlife-aware urban planning and decision support; and (v) to evaluate the potential ecological, social and policy impacts of its implementation into sustainable smart city projects.

The key findings of this paper are summarized as follows: (1) a comprehensive review of the challenges associated with human–wildlife coexistence in rapidly urbanizing smart cities is presented; (2) ecological principles and conservation approaches are combined with new technologies for smart cities, and are integrated in a single planning perspective; (3) a novel multi-layer animal-centered urban planning framework that integrates environmental sensing, wildlife monitoring, spatial intelligence, conflict prediction, and governance support technologies developed in smart cities is proposed; (4) a comprehensive set of ecological, environmental, social and planning performance indicators is presented that allows to evaluate the effectiveness of the framework; and (5) strategic recommendations for policy makers, urban planners, environmental agencies and smart city administrators for promoting sustainable urban development while ensuring long-term conservation of biodiversity and harmonious human–wildlife coexistence are provided [1], [4], [5], [6].

## II. Literature Survey

Urban areas have grown at a fast pace, thereby changing the nature of the ecosystems and leading to more frequent and intense contact with wildlife. The increasing urbanisation of cities results in the loss of natural habitats, or their fragmentation, and in the adaptation of many animal species to urban life. This shift has sparked research interest around the concepts of how sustainable development and biodiversity conservation can be achieved while urban planning. Recent research shows a change in paradigm from traditional anthropocentric planning to more comprehensive integrated planning that takes into account the fact that cities are shared ecosystems and humans and wildlife share space. Urban biodiversity has been increasingly recognised as a vital component in maintaining the ecological stability of urban areas, but also for promoting environmental quality, climate resilience, ecosystem services and human well-being [7, 14]. An early line of study in urban ecology was focused on documenting wildlife distribution, species diversity, habitat fragmentation and the degradation of habitats due to urbanization. The consequences of land use change, pollution and infrastructure development on animal populations were raised in these studies. Later, researchers started investigating how to lessen these effects by implementing green infrastructure, ecological corridors, urban forests, wetlands and the creation of biodiversity friendly landscape designs. This is further reinforced by the development of NbS, which has shown that ecological solutions can make a contribution to the conservation of biodiversity, environmental quality, adaptation to climate change and public health [7] [8]. More recent studies also indicate that the upscaling of NbS in metros can have a significant positive impact on ecological resilience and sustainable cities [8].

Another interesting approach in the current field of research is the coexistence of humans and wildlife and the concept of 'more than human cities'. Recent research instead suggests that coexistence is not just about reducing conflict between humans and animals, but about fostering urban habitats suitable for the coexistence of various animals. There are six factors identified that are required for successful coexistence: habitat availability, ecological connectivity, public awareness, stakeholder collaboration, adaptive governance, and evidence-based planning. In recent years, research on urban

forests and urban management, let alone the management of more-than-human urban environments, underscores the need to treat the presence of wildlife as a part of the urban environment, not an issue to be resolved in the surrounding environment. These methods foster planning tactics that address a range of ecological, social and economic goals [9, 13]. The range of potential solutions to the conservation of urban biodiversity has greatly increased with technology. Smart city technologies like Internet of Things (IoT), Geographic Information Systems (GIS), remote sensing, cloud computing, artificial intelligence (AI), machine learning, digital twins and environmental sensor networks are increasingly used to monitor wildlife and environmental conditions. These technologies allow for the collection of environmental data, detection of wildlife, mapping of habitats, tracking of wildlife movements and predictive ecological analysis in real-time. AI is especially useful for detecting ecological markers, ecosystem services analysis and assisting in making informed urban planning decisions. Spatial AI tools can leverage environmental data and sensing to deliver real-time insights to planners to enhance biodiversity management and habitat restoration [10, 12].

This significant role of urban green space as a multifunctional ecological resources is also noted in the recent literature. Green roofs, urban forests, biodiversity parks, wetlands, ecological corridors, rain gardens and other NbS create habitat for wildlife and offer benefits of improved air quality, help to mitigate urban heat island effects, manage stormwater, enhance carbon sequestration and improve human physical and psychological health. The participation of the population is a key aspect of the effective implementation of biodiversity conservation programs, especially in light of the growing awareness among citizens of the environmental and social importance of urban green spaces.Citizen involvement plays a crucial role in the effective implementation of the biodiversity conservation program, as citizen perception studies show that citizens are increasingly aware of the environmental and social value of urban green spaces. Therefore, the acceptance of society, awareness of the environment, and involvement of citizens have become indispensable elements of sustainable urban planning [11, 14]. Scientists have also highlighted the need for close collaboration between the government, the private sector, the academic community, the community and environmental interests. Public–private–people partnerships are now being used as an effective governance mechanism to enhance urban resilience, to make collective decisions, and to guarantee long-term sustainability measures. These collaborations help facilitate data sharing, coordination of policies, involvement of the community and integrated management to improve the conservation of biodiversity in fast-urbanizing areas [15].

There are some limitations in the current research, however, even though these are significant progress. The majority of studies only focus on one of the research fields linked to ecological conservation, NbS, urban planning, environmental monitoring, or smart city technologies. Many urban planning models are still infrastructure-focused and place emphasis on land use, economic development and transportation effectiveness, and are still not as sensitive as they should be to the needs of wildlife habitats. The same applies for ecological monitoring systems, which are not necessarily associated with urban planning decision making processes and therefore do not have a practical impact on policy development. Current technological solutions are mostly limited to wildlife monitoring, rather than to intelligence-informed planning, predictive conflict resolution and adaptive governance [10], [12]. The other challenge is that there aren't any standardised assessment frameworks that measure ecological, environmental, technological and social outcomes simultaneously. Many factors contribute to the difficulty in comparing planning strategies across cities, including varying biodiversity indicators, spatial assessment methods, ecosystem service assessment methods, and environmental datasets. Moreover, existing siloed data sources, low interoperability between digital platforms, the lack of real-time tracking of ecological processes and a lack of collaboration between stakeholders persist as obstacles to implement ecological considerations in urban planning practice [8] [10] [15]. The limitations underscore the requirement to create an integrated animal-centered urban planning framework that integrates ecological science, smart city technologies, artificial intelligence, NbS, spatial intelligence, environmental monitoring via technology and participatory governance in an interdependent decision support architecture that would improve human–wildlife coexistence in future smart cities.

## III. Human–Wildlife Coexistence in Urban Ecosystems

As cities grow into natural areas, human–wildlife coexistence has become an integral part of sustainable urban development. Urban ecosystems are no longer considered as environments created for the human population, but are seen as dynamic, socio-ecological systems in which humans, animals, plants and the environment constantly interact. In order to achieve coexistence, urban planning measures must be designed to ensure the ecological balance and to ensure economic growth, social well-being and the preservation of biodiversity. Animal centered urban planning (ACUP) is a new paradigm

that brings the needs of animals into the planning, design and management of a smart city. Animal-centred urban planning is an ecological planning concept which views wildlife as part of the urban landscape—rather than its periphery or problem—and takes into account the contributions animals can make to the city. This differs from traditional planning that focus mainly on transport, housing and economic development, which includes consideration of habitat, ecological corridors, biodiversity protection and environmental needs of species as part of land use planning. It calls for the creation of cities that offer nesting places, water and food for a variety of wildlife species, movement routes and safe habitats. Animal centred planning helps to integrate ecological concerns within the planning of infrastructure, which leads to healthier urban ecosystems, enhanced environmental sustainability and improved quality of life for human beings.

Urban wildlife ecology involves the study of the species' survival, adaption and interaction in an urban setting. Birds, mammals, reptiles, amphibians, aquatic organisms, insects and pollinators are just some of the many organisms that rely on cities for their survival and support ecosystem functions. These species provide vital ecosystem functions like pollination, seed dispersal, pest control, nutrient cycling and food webs. Fast urbanization tends to fragment habitats and decrease species diversity, changes migration paths and restricts natural resource access. Maintaining ecological processes which support resilient urban ecosystems, in addition to conserving common and threatened species, is essential to conserving urban biodiversity. Increased frequency of human-wildlife contact as a result of habitat loss, urbanization, climate change, pollution and land-use change. Cities have encroached on forests, wetlands and farmlands, and when wildlife is forced to come into residential and commercial areas in search of food, water, or shelter, they often come into conflict with humans. Animals are usually drawn to populated areas by human activity or artificial water sources, or by the urban vegetation. Consequences of these interactions can include road accidents, crop damage, damage to infrastructure, risk of disease spread, noise, and risk to human and animal safety. The spread of species to new urban environments due to climate change also exacerbates these tensions. Conflict mitigation is an ongoing process that should involve tracking, forecasting risk, raising awareness and adapting management approaches to both ecological and social aspects.

Ecological connectivity is the ability of wildlife to move freely between habitats without being exposed to significant hazards to access food, breeding areas and to be able to exchange genes. Fragmented landscapes limit the movement of animals, reduce biodiversity, and decrease ecosystem's resilience. Green infrastructure is an effective way to accomplish this, creating a network of interconnected ecological infrastructure to facilitate wildlife connectivity through the urban landscape. Combined these features help to increase habitat availability and connectivity, such as in urban forests, green roofs, wetlands, riparian buffers, biodiversity parks, street trees, wildlife corridors and ecological bridges. These green assets can help to facilitate species migration, enhance air quality, manage urban temperatures, curb flooding, capture carbon, and boost resilience to climate change. Implementing ecological connectivity in urban planning promotes the integration of urban infrastructure and programs with natural ecological processes.

Biodiversity conservation has grown in significance for urban planning, as seen in the increasing awareness of the value of biodiversity in global environmental frameworks. Development of resilient, inclusive and environmentally sustainable cities is emphasised in the United Nations Sustainable Development Goals (SDGs) specifically SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), SDG 15 (Life on Land) and SDG 17 (Partnerships for the Goals). Other frameworks of international cooperation, including the Convention on Biological Diversity (CBD), the Kunming–Montreal Global Biodiversity Framework, the New Urban Agenda and the UN Decade on Ecosystem Restoration, continue to support and reinforce the importance of biodiversity issues in government urban governance and urban infrastructure planning. These policies contribute to ecosystem restoration, NbS, stakeholder involvement and evidence informed decision-making to improve the ecological integrity and urban resilience. Aligning animal-centred urban planning with these international frameworks provides opportunities for cities not only to help meet international sustainability goals, but also to help to achieve long-term coexistence between people and animals.

## IV. Smart City Technologies for Urban Wildlife Conservation

Smart city technologies provide new opportunities to enhance the urban biodiversity conservation and to foster harmonious human-wildlife coexistence. Traditional monitoring methods for wildlife are time intensive, labor intensive and geographically constrained such as periodic field surveys and manual observations. Smart city technologies, on the other hand, offer the capability of ongoing environmental monitoring, real-time data collection, predictive analytics, and intelligent decision-making. Advanced Sensing Systems, Artificial Intelligence, Geospatial Technologies, and

Community Involvement all contribute to enhancing the ability of urban planners to understand the behavior of wildlife, recognize ecologic risk, and be able to adaptively manage conservation programs. The technologies are the basis for evidence-based urban planning, which also contributes to the sustainable development of urban infrastructure and biodiversity conservation.

One of the best technologies for monitoring wildlife on a continuous basis in urban ecosystems is the Internet of Things (IoT). The IoT networks consist of various interconnected sensors, camera traps, GPS tracking units, acoustic sensors, environmental monitoring stations and communication gateways that gather real time ecological data. The devices track animal activity, habitat, temperature, humidity, noise, air quality, water availability and vegetation health. The collars and tracking tags used with GPS are useful for determining the movements of wildlife and their habits, as well as corridors of movement, and the smart camera traps automatically take photographs of wildlife with minimal human involvement.

In addition, IoT systems help in the early detection of wildlife that have entered the high-risk urban areas like highways, railway crossings, residential areas, and industrial zones. The real-time alerts produced by sensor networks can help with interventions in a timely fashion, thereby lowering the loss of life of wildlife and limiting its interaction with humans. In addition, cloud-based IoT platforms can also facilitate the centralised storage, visualisation and sharing of ecological data between environmental agencies, researchers and cities, enhancing joint conservation initiatives. The advent of Artificial Intelligence (AI) has revolutionized wildlife conservation, allowing for the processing and analysis of vast amounts of ecological data in an automated manner. The machine learning and deep learning algorithms can recognize the animal species with accuracy from pictures, videos, thermal cameras, drones and sounds. The use of computer vision techniques helps to substantially decrease the amount of manual image annotation, and increases the efficiency of monitoring and species detection accuracy.

AI models can identify animal behavior, animal population density, habitat type, illegal activity, and animal future movement patterns. Another benefit of the predictive analysis for conflict prevention is an ability to pinpoint a zone that is likely to contain wildlife crossings and anticipate areas where human–wildlife interactions may be more likely. Using NLP, the information provided by citizens and social media can be analysed and used to detect new biodiversity problems. AI-powered decision-support systems combine various environmental data, which can help planners assess the conservation options available and prioritize conservation actions based on science.

The use of Geographic Information Systems (GIS) and remote sensing technologies provides extensive spatial information needed for urban wildlife management. GIS can be used to visualize, analyze and manage geospatial data on land use, habitat distribution, vegetation cover, transportation network and biodiversity hotspots. GIS can be used to overlay more than one environmental dataset to help identify ecological corridors, habitat fragmentation, migration routes and priority conservation areas. Satellite imagery, aerial photography, and drone-based and LiDAR-based technologies enable monitoring of changes in the environment over extensive areas. These technologies enable the monitoring of land use changes, vegetation dynamics, urbanization, water resources and habitat degradation. The high-resolution of satellite imagery and the ability to analyze it through GIS allows planners to assess ecological connectivity and to model the effects of future construction projects on wildlife habitat. Thus, spatial intelligence, based on GIS, is a key element in the creation of a cityscape conducive to biodiversity.

Digital twin technology is a major breakthrough in smart city planning and is the creation of a virtual copy of a real city. A digital twin combines the information from the sensors, the environment, infrastructure models, a traffic model and biodiversity observations as a dynamic simulation platform. These virtual environments can be utilized to test various development scenarios in the design phase prior to construction of physical infrastructure. Wildlife movement, habitat change, climate change, ecological connectivity and urban growth simulation are possible with digital twins. They help to forecast potential impacts of new roads, structures, transportation systems or green infrastructure projects on biodiversity and human–wildlife interactions. The integration of AI, GIS, IoT, and environmental models with digital twins enables proactive planning and adaptive management, empowering decision-makers to make informed choices that optimize urban development while minimizing ecological impacts. Mobile apps and crowd-sourced environmental data are increasingly helping to make citizens part of urban biodiversity monitoring. Citizen science programs involve citizens to contribute to the reporting of wildlife observations, habitat quality, invasive species, injured wildlife, and environmental alterations through the use of smartphone and online reporting forms. They provide significantly greater spatial and temporal coverage as well as enhancing public consciousness of the need for the conservation of biodiversity over traditional ecological surveys.

Mobile apps that include GPS, image recognition and geotagging enable the user to upload images, video and GPS data that helps build urban biodiversity databases. Crowdsourced datasets extend information gathered from IoT sensors and remote sensing systems, by providing observations from a localized area that could otherwise be unobserved. Moreover, citizen involvement fosters greater cooperation and civic engagement, enabling more effective partnerships between local government, research, conservation groups and urban residents that can help to increase environmental education and community involvement in governance.

## V. Proposed Animal-Centered Urban Planning Framework

The proposed Animal-Centered Urban Planning Framework (ACUPF) is an integrated framework that can use the coordinated application of ecological principles, advanced digital technologies, and adaptive urban governance to promote sustainable human-wildlife coexisting in smart cities. The framework goes beyond the current models of urban planning that largely focus on "infrastructure first" development and economic growth, including wildlife habitat needs, biodiversity protection, ecological connectivity and environmental sustainability in the urban planning and decision-making process. The framework is a multi-layer, intelligent framework in which each layer of the intelligence system in the framework interacts constantly with each other and with the environment, monitoring the wildlife, doing the spatial analysis, making the prediction and making the policy decision. The framework integrates real-time environment data with AI and geospatial tools to promote proactive ecosystem management solutions and reduce human-wildlife conflict.

The main goal of the proposed framework is to develop an intelligent, adaptive and biodiversity-friendly urban planning framework that can facilitate long-term human-wildlife coexistence. The goal of the framework is to continually monitor the urban environment, evaluate wildlife habitats, identify areas of ecological connectivity, forecast conflict areas and make planning recommendations. It also aims to integrate the concept of conservation of biodiversity in transportation planning, land use planning, development of green infrastructure, disaster resistance and adaptation to climate change. Another key goal is to deliver scientific information and knowledge to urban planners, decision-makers, environmental agencies and communities that can help them make sustainable decisions without compromising ecological integrity.

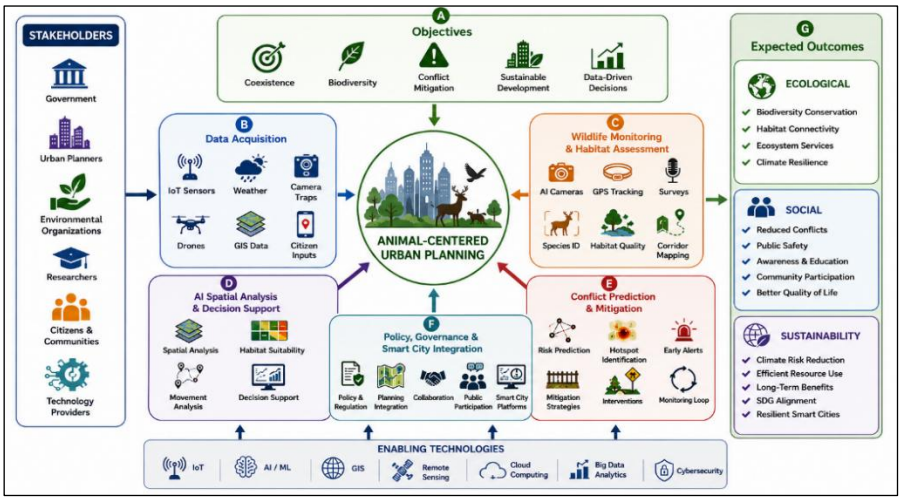



**Figure 1. Proposed Animal-Centered Urban Planning Framework for Smart Cities**

The proposed Animal-Centered Urban Planning Framework (Figure 1) combines ecological conservation, smart city technologies and urban governance to create sustainable human–wildlife interaction. It starts with the data gathering of the environment through the use of IoT sensors, GIS, drones, camera traps, and citizen contributions, and continues with data gathering of wildlife and habitat assessment. The data is then analyzed using AI and spatial data to determine habitat suitability, ecological corridors, and areas of potential conflicts. The framework suggests suitable mitigation measures, and facilitates informed urban planning using policy integration and inter-institutional cooperation based on these insights. Overall, the results are better biodiversity conservation, fewer human–wildlife conflicts, better ecosystem resilience and the creation of smart, sustainable and wildlife inclusive cities aligned to the Sustainable Development Goals (SDGs).

The first layer of the framework is devoted to collecting all-encompassing environmental data from a variety of sources throughout the urban environment. Climate, vegetation health, air quality,

water, land use, noise pollution, traffic density and habitat characteristics are all measured on a continuous basis via the Internet of Things (IoT), weather stations, camera traps, acoustic monitoring, satellite imagery, remote sensing and Geographic Information Systems (GIS), and environmental databases. Data from citizen observations, via mobile apps and crowdsourcing platforms, is also integrated into the data acquisition layer. This layer will facilitate the centralized integration of heterogeneous environmental data in a cloud-based platform and create a dynamic digital map of the urban environmental conditions, which will provide the basis for intelligent biodiversity assessment.

The second layer is used to monitor wildlife populations and habitat conditions on an on-going basis across the city. Information on species distribution, migration routes, breeding locations, habitat use, and behavioural patterns are gathered from camera traps using AI, GPS collars, unmanned aerial vehicles (UAVs), acoustic sensors and environmental monitoring systems. Using images and videos captured by a camera, computer vision algorithms are used to automatically detect animal species and estimate the abundance of the animals. Habitat assessment models provide a way to characterize ecological quality based on the presence of vegetation cover, habitat fragmentation, food availability, water accessibility, nesting habitat, biodiversity richness and ecological connectivity. The layer also highlights areas of biodiversity hotspot, ecological corridor and habitat degradation that need conservation/restoration. An ongoing ecology assessment allows planners to not only recognize changing ecological conditions, but to prioritize conservation efforts based upon them.

The third layer is the 'intelligent core' of the proposed framework. AI, machine learning, deep learning, Geographic Information Systems (GIS) and spatial analytics are tools that combine to work on environmental and biodiversity data to produce knowledge that can be used for action in urban planning. Predictive models pinpoint wildlife movement corridors and pathways, biodiversity hotspots, habitat suitability, and environmentally sensitive areas. The decision-support engine compares different urban planning scenarios to simulate the growth of infrastructure, development of transportation, implementation of green infrastructure and changes of land use. The Multi-Criteria Decision Analysis (MCDA) techniques can help planners to reconcile ecological conservation objectives with socio-economic development objectives. AI-generated risk maps can be used to prioritise habitat restoration activities, wildlife crossing structures, ecological corridors and biodiversity-friendly urban infrastructure. The system constantly adapts recommendations based on real-time environmental data, allowing for adaptive urban planning.

This layer has been developed specifically to minimise human-wildlife conflict by using predictive analytics and proactive measures. The AI models use historical wildlife sighting data, traffic volumes, urban development, seasonal migration patterns, climatic data, and habitat suitability to help pinpoint regions that are most likely to involve human–wildlife interactions. All of these potential conflict areas are monitored on a regular basis, including highways, railway crossings, residential areas, industrial areas and recreational parks. Early warning systems produce automatic notifications to municipalities when animals enter areas of risk in the city. The framework also identifies mitigation actions such as wildlife crossings, ecological fencing, habitat restoration, traffic control, signage, waste management and public awareness programs. These measures not only save lives, but are also beneficial to the environment and public safety.

The last operational level is the embedding of ecological intelligence in urban governance and smart city management systems. The information produced by the previous layers assists with evidence-based policy making, sustainable land-use planning, plans for biodiversity conservation, environmental impact assessment, disaster preparedness and climate resilience planning. Proposed development projects can be assessed prior to implementation by ecological consequences. The governance layer advances collaboration amongst municipalities, environmental agencies and agencies, urban planners, conservation groups, academic research, technology providers and the local community. Open Data Platforms and digital dashboards enhance transparency and enable public participation in biodiversity conservation efforts. The planning framework is also designed to be consistent with international sustainable development policies, strategies for the conservation of biodiversity, and Sustainable Development Goals (SDGs), minimizing planning that addresses needs inconsistent with the global environment.

The adoption of the new Animal-Centered Urban Planning Framework is anticipated to result in tremendous ecological, social, economic and governance outcomes. The framework has been enhanced for its ecological merits, including increased biodiversity, restoration of habitat connectivity, increased ecosystem resilience, protection of endangered species, and ecosystem services like pollination, carbon sequestration, flood control and climate adaptation. Ongoing environmental monitoring can help identify ecological degradation early and can aid in implementing conservation actions in time to prevent degradation. Socially, the framework

reduces human–wildlife conflict; increases public safety; makes the public more aware of the environment; involves citizens; and contributes to a healthier and greener urban environment. Intelligent decision-support systems: more efficient planning, minimisation of ecological damage due to infrastructure development, optimisation of resource use for conservation activities. On an economic level, there is a long-term advantage to planning for biodiversity, through reduced environmental restoration costs, sustainable tourism and increased value of green infrastructure and urban resilience to climate-related challenges. The smart technologies further contribute to improved operational efficiency by facilitating data-driven management of urban ecosystems.

## VI. Assessment Frameworks and Performance Indicators

Assessment frameworks are crucial tools for measuring the success of animal-centred urban planning as they offer quantifiable metrics for assessing ecological, environmental, social and governance outcomes. A detailed assessment framework allows urban planners and policy makers to track the conservation of biodiversity, assess habitat quality, quantify human–wildlife interactions, and quantify the overall sustainability of urban ecosystems. Combining ecological indicators with smart city data and decision-support tools enables cities to constantly assess planning results and take adaptive management decisions. Ecological indicators are used to assess the status and resilience of urban ecosystems, based on the ecological assessment of biodiversity and habitat conditions. Examples of these indicators involve the number of species, species abundance, variety of habitats, amount of habitat cover, pollinator populations, available ecological corridors, ecosystem service capacity, and conservation status of native species. These indicators are useful for the assessment of biodiversity hotspots, ecosystem changes and for the assessment of the efficacy of habitat restorations. Human–wildlife conflict metrics include the number, intensity and spatial extent of human-wildlife conflicts. Wildlife-related road accidents, property damage incidents, wildlife mortality rates, density of conflict hot spots, animal rescue records, disruptions of animal migrations in the season, and public safety incidents are critical performance indicators. These metrics can help planners recognize areas of high risk and put measures in place to mitigate the risk, including wildlife crossings, ecological fencing and early warning systems.

Environmental quality indicators are used to gauge the state of an urban habitat, and its ability to sustain biodiversity. These include air and water quality, green space availability, urban tree canopy coverage, vegetation health, landscape fragmentation, ecological connectivity index, habitat suitability score, carbon sequestration potential and climate resilience. These indicators offer important information for assessing the integrity of ecosystems and in the design of green infrastructure networks. Social indicators measure the level of public awareness, involvement of stakeholders and community support for wildlife conservation programmes. These are citizen involvement in biodiversity monitoring, citizen's perception of urban wildlife, environmental education programmes, volunteering, adoption of citizen science applications, and satisfaction with the urban green spaces. Conservation success with strong community involvement and collaboration in urban governance. Multi-Criteria Decision Analysis (MCDA) is a systematic method to account for ecological, environmental, economic and social goals in urban planning. The approach combines several performance criteria to provide a ranking of the planning alternatives according to their overall sustainability. Decision-makers can give relative weights to their priorities for biodiversity conservation, habitat connectivity, infrastructure development, economic feasibility, public safety and community preferences, allowing for transparent and evidence-based planning decisions. Integrating MCDA with AI-powered spatial analysis and GIS allows urban planners to determine the best development pathway in terms of minimizing ecological effects and maximizing long-term development sustainability and human-wildlife coexistence.

| Performance Criterion | Conventional Planning | Proposed Animal-Centered Framework |
|---|---|---|
| Biodiversity Conservation | Low | High |
| Habitat Connectivity | Limited | Comprehensive Ecological Corridors |
| Real-Time Environmental Monitoring | Not Available | IoT-Based Continuous Monitoring |
| Wildlife Monitoring | Periodic Manual Surveys | AI + IoT + Computer Vision |
| Conflict Prediction | Reactive | Predictive AI Analytics |

| | | |
|---|---|---|
| GIS Decision Support | Limited | Advanced GIS & Spatial Intelligence |
| Citizen Participation | Moderate | Active Citizen Science |
| Sustainability Integration | Partial | Fully Integrated with SDGs |
| Adaptive Planning | Low | High |
| Policy Support | Traditional Planning | Smart Governance & Digital Decision Support |

**Table 1. Comparative Evaluation of Urban Planning Approaches**

Table 1 highlights the similarities and differences between traditional urban planning and the concept of Animal-Centered Urban Planning in various planning and sustainability aspects. The comparison reveals that the proposed framework has a much more positive impact on improving the conservation of biodiversity, connectivity of habitats, real-time environmental monitoring, AI-based wildlife monitoring, predictive conflict management and GIS-based decision-making. It also fosters increased citizen engagement, adaptive planning and better connections to the Sustainable Development Goals (SDGs). In sum, the proposed framework offers a more complete, and sustainable, framework for the development of smart cities that are wildlife inclusive than traditional urban planning strategies do.

The framework proposed shows significant progress in the ecological, technological and governance aspects. AI-driven habitat assessment allows for early detection of habitat degradation and predictive analytics brings a great reduction in human–wildlife conflict. Planning for green infrastructure enhances habitat connectivity and biodiversity protection. The incorporation of these technologies, such as IoT, GIS, cloud computing, and decision support dashboards, contributes to adaptive urban management and efficient resource distribution.

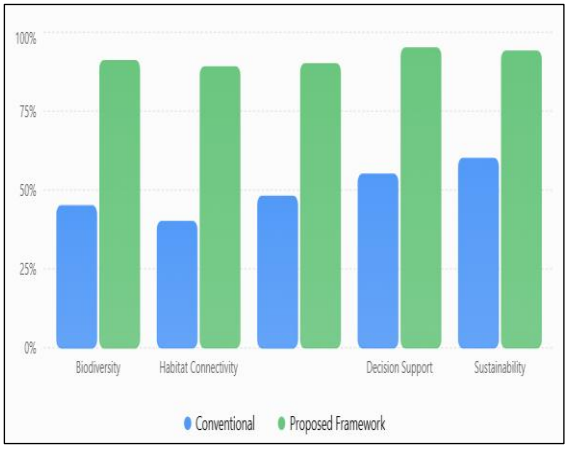



**Figure 2. Comparative Performance of Conventional and Proposed Frameworks**

Figure 2 shows that the proposed framework consistently performs better in terms of biodiversity conservation, ecological connectivity, conflict reduction, intelligent decision support and overall sustainability.

The proposed framework has significant advantages, but there are also several issues to implement it. Implementing IoT, AI and cloud-based environmental databases is very costly and technically demanding. Sourcing environmental data from multiple agencies, each with different data sources, formats and resolutions, can be challenging due to interoperability and data standards concerns. There are not many opportunities to establish ecological corridors and biodiversity parks in the cities due to the scarcity of urban land. Furthermore, a lack of ecological expertise, lack of clear responsibilities, lack of funding over the long term and lack of public awareness can be limiting factors for adoption. Solving these challenges will take an interdisciplinary approach, common data protocols, and continued policy support.

| **Challenge** | **Impact** | **Possible Solution** |
|---|---|---|
| High Deployment Cost | Delays implementation | Government investment & PPP models |
| Data Integration | Poor interoperability | Standardized data platforms |
| Limited Urban Space | Habitat fragmentation | Vertical greening & green corridors |
| AI Model Reliability | Decision uncertainty | Continuous model training |
| Institutional Coordination | Slow policy execution | Integrated governance framework |
| Public Awareness | Low participation | Citizen engagement programs |

**Table 2. Major Implementation Challenges**

The key challenges to be overcome for the implementation of the proposed animal-centred

urban planning approach in smart cities are summarised in Table 2. The challenges and problems involve are: high deployment cost, the integration of heterogeneous environmental information, ecological infrastructure in urban areas which is in short supply, reliability of AI models, institutional coordination, and lack of public awareness. The table also offers actionable recommendations, including: citizen engagement programs, integrated governance, ongoing AI model development, green infrastructure development, standardized data platforms, and public–private partnerships. To tackle these challenges is crucial for the successful implementation and sustainability of smart cities with wild life.

With the introduction of intelligent wildlife monitoring systems come ethical and regulatory concerns. Disturbance to wildlife must be kept to a minimum and surveillance, drone monitoring, GPS tracking, and environmental sensing need to adhere to the guidelines for privacy regulations. All urban biodiversity data need to be managed securely, to avoid the misuse of sensitive ecological data. The planning decisions should be transparent, explainable and scientifically validated. In addition, national urban planning policies need to be consistent with international biodiversity agreements and Sustainable Development Goals, and need to encourage equitable access to green infrastructure and community engagement.

Going forward, more research and development is needed on the adaptive, intelligent and scalable urban biodiversity management systems. New technologies like digital twins, autonomous drones, edge AI, federated learning and next-generation environmental sensors have the potential to greatly improve real-time ecological monitoring. The species migration and habitat degradation can be predicted by developing the advanced machine learning models and the ecological change due to climate change can be predicted. Scientists need to develop a uniform assessment approach and an agreed set of biodiversity indicators to help compare smart cities across the globe. Additionally, there is a need to strengthen the economic valuation of ecosystem services, to ensure that urban ecosystems are more resilient, to involve the residents in managing and conserving biodiversity and to incorporate biodiversity concerns in digital smart city platforms.

## VII. Conclusion and Future Outlook

The problems of how to balance infrastructure development and biodiversity conservation have become more acute due to the high urbanization rates, thus making human–wildlife coexistence a key goal of sustainable smart city planning. This paper introduced a comprehensive overview of animal-centred urban planning principles, urban wildlife ecology, smart city technologies, assessment frameworks and international initiatives on sustainability that all work towards wildlife-inclusive urban planning. The study also introduced an integrated Animal-Centered Urban Planning Framework that integrates Internet of Things (IoT), Artificial Intelligence (AI), Geographic Information Systems (GIS), remote sensing, digital twins and participatory governance within a single decision support system for monitoring biodiversity, evaluating habitats, predicting conflicts between humans and wildlife, and providing evidence-informed urban planning. The proposed framework provides a proactive, data-driven, adaptive approach that increases ecological connectivity, enhances biodiversity conservation, improves environmental quality and reduces human–wildlife conflict, while promoting resilient urban growth, which is superior to conventional planning strategies. The comparison highlights how ecological intelligence can be applied to smart technologies for more efficient conservation planning, improved resource management, and enhanced collaboration with stakeholders. Smart cities will need to change from technology-based to nature-positive, wildlife-inclusive cities and become embodied in every planning decision for future cities. AI, IoT, digital twins and geospatial analytics will continue to enhance urban biodiversity management, along with communities' participation and public policies that support it. The proposed framework is a scalable framework for future research and implementation which will help to achieve the Sustainable Development Goals (SDGs) and to ensure resilient cities, which will have humans and wildlife living harmoniously for generations to come.

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