Green Infrastructure in the 15-Minute City: Ecological Resilience and Urban Sustainability

Hadi Aboulfazli[1, *] - Fariba Rostami[2] -Roza Vakilinezhad[3]
[1, *] Khayyam University, Mashhad, Iran
[2] University of Maryland Eastern Shore, Maryland, USA
[3] Shiraz University, Shiraz, Iran

ABSTRACT

Nowadays ecological and social challenges of cities make sustainable urban planning frameworks increasingly essential. This research addresses a need to respond to critical urban issues of biodiversity loss, urban heat islands and carbon sequestration simultaneously while improving the livability and sustainability of cities.This study uses a review-based methodology to investigate the relationship between Green Infrastructure (GI) and the 15-minute city framework. The review was rooted in a large document foundation gained through a comprehensive literature search from sources such as databases like Google Scholar, ScienceDirect and Springer. It identifies key concepts, challenges, and opportunities in urban planning, environmental design and climate adaptation through a review of scholarly literature, policy documents and case studies. The study explores how GI can improve the 15-minute city model, using global examples such as Paris, Melbourne and Portland. Sustainable urban land use strategies are shown by initiatives such as Melbourne's "Grey to Green" project and the "Green Factor" tool. The research also considers emerging tools such as GIS-based systems and participatory planning models for addressing equity challenges and precluding green gentrification. GI's environmental and social benefits, including mitigating urban heat islands, conserving biodiversity, and increasing carbon sequestration are evaluated alongside its social benefits, including fostering social interactions, reducing stress and increasing mental health. These effects are quantified using ecosystem service evaluation frameworks. The study compares selected cities and identifies best practices and scalable strategies for integrating GI into dense urban environments. This review synthesizes literature and case studies to offer actionable insights for improving GI in 15-minute cities, including strategies to improve ecological resilience, social equity, and measuring environmental and societal impacts.

Keywords: 15-minute city, Green Infrastructure (GI), Sustainability, Urban resilience, Social equity

1. INTRODUCTION

The concept of the 15-minute city has quickly become an innovative model for developing a sustainable urban environment in urban planning. It promotes neighborhood-oriented urban planning and organizing where people can work, learn, be treated, and relax without having to drive for more than 15 minutes on foot or by bike (Figure 1). This idea helps solve large problems like sprawl, overreliance on private auto, and climate change through decentralization of city functions (Khavarian-Garmsir et al., 2023; Allam et al., 2024).

The increased concerns over climate change, health, and equity in cities around the world, have led to the application of the 15-minute city model globally. Its core components include proximity, diversity, density, flexibility, and connectivity and very well suit sustainability aspirations, including mitigating greenhouse gases, improving public health and promoting social inclusion (Figure 2). The emphasis of the model on local economies and bottom-up planning has rendered it as a strategic approach to urban adaptability in the context

of rising environmental and social risks (Khavarian-Garmsir et al., 2023; Allam et al., 2024; Papasa et al., 2023).

However, the value of the 15-minute city concept which refers to proximity and accessibility as the key driver of urban development, is in its ability to incorporate the integrated sustainable urban measures responding to ecological challenges. Of these principles Green Infrastructure (GI) assumes a critical position as it supports the framework's principles of proximity, connectivity, and flexibility, Through the integration of GI within urban architecture, the 15-minute city model improves the ecology of cities and makes them more resilient in the face of the increasing effects of climate change.

Fig. 1. *A 15-minute city designed for pedestrians and cyclists, where residents can easily reach their destination without the need for a car (https://www.weforum.org)*

Green Infrastructure is defined as a system of natural and semi-natural areas that are connected and which deliver essential ecosystem services to human communities (Benedict & McMahon, 2002). Green infrastructure (GI) planning link ecological and social objectives, which help to support the conservation of species, climate change mitigation, and the shift to green economy urban systems (Pauleit et al., 2011). GI was developed in the 1990s as are s for combating urban challenges like bio-diversity loss, climate change, and urban heat islands (Firehock, 2010); GI offers the right systems for these purposes. It provides ecosystem services that have a direct impact on urban mobility, public health and environmental justice (Hansen et al., 2015).

The ability of GI to mitigate urban heat islands (UHIs) is one of the main benefits of GI within the framework of the 15-minute city. GI improves the quality and distribution of green spaces, reducing the thermal effects of impervious surfaces, and improving the walkability and cyclability of urban environments (Moreno et al., 2021). The benefits of GI must be accessible to all urban dwellers, and quality and equitable distribution of green spaces are still essential (Davies et al., 2015).

Integration of GI into the design of compact and multifunctional urban spaces offers solutions to critical ecological challenges including biodiversity loss, urban heat islands, and carbon sequestering. This integration demonstrates the need for an optimal, networked approach to urban planning that balances the value of green spaces with the reality of densified, urban conditions. However, this balance presents significant challenges. In cities where land use is rapidly increasing and competing, the ecological and social benefit of GI is maximized, which requires nuanced research.

This research aims to explore how urban green infrastructure within the framework of 15-minute cities can be optimized to address pressing ecological challenges such as biodiversity loss, urban heat islands, and carbon sequestration. This study also synthesizes existing research to identify the conceptual review and analytical

tools that best quantify the ecological benefits of green spaces in these urban environments. It will also discuss how this conceptual review can contribute to the development of scalable urban sustainability models that improve both the environmental and social aspects of the 15-minute city model.

This study adopts a review-based methodology to synthesize existing research on green infrastructure and the 15-minute city framework to achieve these goals. This methodology reviews case studies, scholarly literature and relevant policy documents to identify key challenges and opportunities for ecological and urban planning integration. This approach ensures that current practices are evaluated comprehensively and that insights and recommendations are generated for optimizing green infrastructure in 15-minute cities.
This review aims to understand thoroughly how the green infrastructure can be integrated into the 15-minute city framework. This will provide an understanding of strategies to improve ecological resilience, while developing robust evaluation methods for assessing the environmental impacts of these interventions.

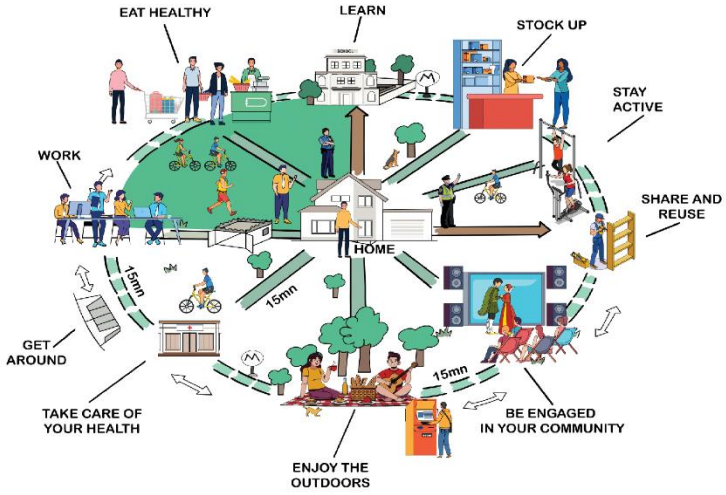

Fig. 2. *A model of 15-minute city and its components (Source: https://www.burohappold.com)*

2. LITERATURE REVIEW, CONCEPTUAL FRAMEWORK

2.1 The Concept of 15-Minute Cities

The 15-minute city, as embraced by Carlos Moreno, is a simple rethinking of urban planning focusing on local accessibility and community wellbeing; prioritizing sustainability. This model at its core, posits that all essential services such as housing, work, education, healthcare and leisure should be within 15 minutes by walk or bike ride of home (Moreno et al., 2021; Teixeira et al., 2024). This human-centered approach goes straight to the heart of the problems associated with car dependency, urban sprawl and environmental degradation. The model promotes proximity and active commuting, making for healthier lifestyles, reduction of greenhouse gas emissions and tighter community ties (Teixeira et al., 2024).

Another characteristic of the 15-minute city is the connection between activities and density and adherence to an equitable service perimeter. These principles include the Scarce and limited use of private cars, and thus the promotion of environmentally friendly transport. At the same time, the conversion of car-dominated space into pedestrian and green public domain, infrastructure, and multi-functional buildings enhances the quality of neighborhoods and makes communities denser and more resilient, as the COVID-19 pandemic has shown (Di Marino et al., 2023).

The COVID-19 pandemic also increased the focus on local accessibility, and therefore, the 15-minute city model was brought up again. In response, some cities such as Paris, Melbourne, and Barcelona have adopted some elements of this model such as increasing the size of pedestrian areas, constructing cycling infrastructure, and shifting urban services to smaller centers. In addition to making cities more resilient to crises, these initiatives have been responsible for producing more self-sufficient, sustainable cities (Teixeira et al., 2024; Moreno et al., 2021).

As cities continue to look for ways of achieving sustainable and resilient cities the 15-minute city model can be helpful as a framework that addresses social equity, cohesion and environmental impact. It presents a potential solution for cities that have to find ways of managing the social costs of urbanization and creating a healthier and more equitable urban environment (Moreno et al., 2021; Di Marino et al., 2023).

2.2 Ecological Challenges Addressed by Green Infrastructure

The integration of Green Infrastructure (GI) within the 15-minute city model solves several ecological problems such as loss of species, UHIs, and carbon sequestration. Habitat fragmentation and loss of species diversity have been major consequences of urbanization on natural systems. Green infrastructure, including urban woods, gardens, and wetlands, is a home to urban fauna, which enhances species diversity even in highly populated areas (Ariluoma et al., 2021; Liu et al., 2024). For example, the integration of numerous plant species in the urban environment preserves the native vegetation and animals, in addition to increasing the capacity of the urban ecosystem to provide ecosystem services given the effects of urbanization (Dong et al., 2024).

2.3 Urban Heat Islands (UHIs)

Heat islands in cities are one of the biggest environmental problems of the contemporary world. urban areas with impervious surfaces such as asphalt and concrete absorb and retain heat, causing cities to experience higher temperatures than their rural surroundings (Shirgir et al., 2019). This aggravates energy consumption for cooling, raises the incidence of heat-related illnesses, and reduces the standard of living in cities. Green infrastructure offers a biological solution to these impacts through shading, evapotranspiration and the creation of green areas that reduce heat (Liu et al., 2022). For instance, tree canopies and urban forests can greatly decrease the temperature of the surrounding environment, enhance the thermal quality of urban environments, and decrease the need for energy to cool down the environment (Ariluoma et al., 2021; Dong et al., 2024).

2.4 Carbon Sequestration

In the face of accelerating urbanization, cities are seen as increasingly important areas for carbon sequestration. Photosynthesis and biomass and soil storage of captured atmospheric CO_2 occur in urban green spaces, including parks, urban forests and residential greenery. For example, research in Helsinki finds that combining urban tree planting with biochar integration increases the carbon storage capacity of urban green spaces by a factor of 3, making them better at mitigating carbon emissions (Ariluoma et al., 2021). Studies in India also indicate that urban forests are important in improving air quality and reducing carbon emissions as well as providing substantial ecological benefits (Bherwani et al., 2022).

Long-term climate goals such as carbon neutrality require the inclusion of green infrastructure into urban policy and design. Cities can improve their environmental footprint by increasing green spaces that promote carbon sequestration and improving the quality of life for their residents (Shirgir et al., 2019; Liu et al., 2024). The increasing recognition of GI's potential to mitigate biodiversity loss, urban heat islands and carbon sequestration motivates its integration into the 15-minute city framework. When combined with principles of proximity, connectivity, and multifunctionality, these ecological strategies help urban areas remain resilient to climate change while delivering a high quality of life for all residents.

2.5. Optimizing Green Infrastructure in 15-Minute Cities

2.5.1. Integration into Urban Design

The 15-minute city model language centres along proximity and accessibility and to achieve this, the integration of Green Infrastructure (GI) is key. Cities can embed GI into urban designs to overcome not only environmental problems such as carbon sequestration and heat island mitigation, but also promote walkability, active mobility, and urban livability. To achieve this double purpose, green spaces including pocket parks, green roofs, and vegetated corridors can be designed in a strategy to integrate with the urban fabric and contribute to manifold ecological, social, and recreational spaces (Khavarian-Garmsir et al., 2023). With the potential to increase biodiversity, they also act as a public space for community engagement created through relaxation and recreation as well as social interaction.

In addition, the inclusion of GI into urban design helps integrate fragmented green spaces into wider ecological networks aiding species movement and promoting ecosystem resilience. When designed with connectivity, these green corridors not only benefit urban biodiversity, but they also supply vital ecosystem services to enhance the overall sustainability of the urban environment (Pozoukidou & Chatziyiannaki, 2021;

Luo et al., 2022). These strategies fit nicely with the focus of the 15-minute city on local accessibility because residents are able to experience the ecological benefits of green infrastructure without having to travel far.

2.5.2. Space Efficiency and Multifunctionality

In densely populated urban areas space efficiency is critical. Green infrastructure must be multifunctional to achieve environmental functions (e.g., stormwater management and air quality improvement), social benefits (e.g., public spaces for recreation and relaxation), and economic benefits (e.g., water and energy savings). GI's multifunctionality enables cities to more fully exploit the land they have, for ecological and social aims. For example, green roofs reduce stormwater runoff at the same time they offer recreational areas for residents. Vegetated street medians and linear parks are also similarly used to improve urban aesthetics and reduce the urban heat island effect (Pozoukidou & Chatziyiannaki, 2021).

Tactical urbanism is one way to make the most of space by reusing underused or vacant urban spaces to create multipurpose green areas. Projects like community gardens or temporary green spaces in parking lots or in abandoned sites can convert overlooked spaces into useful advantages, boosting urban sustainability and also engaging the community (Abdelfattah et al., 2022). Furthermore, they actively demonstrate both the need for flexible and adaptive approaches to urban planning in the face of scarce land, and the improvement of life quality for residents.

2.5.3. Environmental and Social Benefits

Green infrastructure offers a wide variety of environmental and social benefits, and is a key element of the 15-minute city model. Green spaces are strategically placed to intercept air pollution, reduce urban heat islands and enhance biodiversity to the overall environmental quality of urban areas. We know that exposure to green spaces reduces stress, promotes physical activity and improves mental health — especially in densely populated areas (Luo et al., 2022). These benefits bring home the importance of GI in urban planning that would help produce healthier, liveable cities.

One of GI's biggest advantages is its social inclusivity (Figure 3). In the struggle to guarantee equitable access to green spaces to foster social cohesion and remove differences between economically urbanized groups, social justice and sustainability have an important role to play. If green spaces are built to be inclusive for all, they can be community hubs, providing opportunities to interact and help create a sense of belonging.' Challenges, such as "green gentrification," where the development of green spaces pushes property values higher, displacing low-income residents, must be dealt with. To continue to be accessible to marginalized communities' green spaces need participatory planning and equity-based policies (Khavarian-Garmsir et al., 2023).

Fig. 3. *Social inclusivity in 15-minute which promotes equity and community cohesion (Source: https://momentummag.com/)*

2.6. Challenges and Strategic Solutions

GI implementation within 15-minute cities faces its challenges. One of the most pressing problems is owing to the limited land availability, governance fragmentation and the uneven distribution of green spaces in urban areas. To achieve these challenges, cities need to embrace innovation and strategic planning. For example, digital tools and big data that are used to map potential green space can help determine where interventions occur in the least served area. Moreover, citizen participation is facilitated for the planning and designing of green spaces to ensure that these areas address the broadened needs of the urban population (Abdelfattah, Deponte, Fossa, 2022).

The tactical urbanism provides one remedy for these problems by permitting cities to hustle incrementally inhabit unutilized open space by making it green. For example, Paris's transformation of Paris's Rue de Rivoli into a pedestrian-friendly and green corridor shows how cities can re-purpose space to make people (Pozoukidou & Chatziyiannaki, 2021). Therefore, long-term planning strategies like infrastructure upgrades and digital innovation are also important for making GI interventions sustainable and adaptable in the long term.

2.7. The Multifaceted Role of Urban Green Infrastructure in Enhancing 15-Minute Cities

Urban green infrastructure (UGI) is key in the creation of 15-minute cities by shaping their functionality and livability. Green corridors and shaded cycling lanes, as well as well-maintained sidewalks, are key components of UGI, which in turn significantly influences daily travel behavior by making walking and cycling commute more comfortable and enjoyable. In addition to giving aesthetic value, these UGI elements go beyond to make sure that the spaces they create in urban areas are not just sustainable, but comfortable and pleasant to use. UGI emphasizes the emotional and practical aspects of urban mobility to support the holistic vision of 15-minute cities in which accessibility and livability are equally important (BaghaiePoor, 2023).

Diverse UGI components are integrated to maintain a balance between accessibility, environmental sustainability and user experience. Active mobility provides UGI the opportunity to contribute to more sustainable and equitable urban environments and to resilient cities vulnerable to future ecological and social challenges.

3. CASE STUDIES: GLOBAL EXAMPLES OF GREEN INFRASTRUCTURE IN 15-MINUTE CITIES

3.1. Paris: Urban Greening Projects and Accessibility Strategies

Paris is one of the leading cities in the world in realizing the 15-minute city concept, spearheaded by Mayor Anne Hidalgo as a model for greater accessibility and sustainability. The development of urban green infrastructure has been key to Paris's strategy of reducing car dependence and improving the quality of life for its inhabitants, one of the city's main strategies. As one example, the transformation of the Champs-Élysées into a pedestrian-friendly green corridor not only beautifies the city, but also reduces urban heat island effects and improves air quality (Moreno et al., 2024). Apart from these iconic projects, Paris has dedicated itself to building neighborhood-scale green spaces, including converting schoolyards into multifunctional 'oasis courtyards' that function as community hubs. It brings essential services closer and closer to residents meeting the core principles of the 15-minute city, reducing the need for distance long-distance travel in the city. In addition to enhancing environmental quality, the integration of green infrastructure in Paris facilitates community building and social interaction, and is helping to make the city both more resilient to climate change and to shrinking green spaces (Moreno et al., 2024).

3.2. Melbourne: Mitigating Heat Islands and Promoting Biodiversity

Melbourne places green infrastructure at the forefront of its urban planning strategies to tackle two of the most pressing ecological challenges of urbanization: the urban heat island phenomenon and biodiversity loss. The 'Grey to Green' program, another of the city's flagship initiatives, transforms underused inner-city space into thriving green areas. This includes building rooftop gardens, vertical green walls and expanding public parks (Graells-Garrido et al., 2021). In addition to serving as a habitat for local flora and fauna, these green spaces also improve urban resilience by moderating extreme heat and saving energy consumption.

Melbourne also has introduced tools like the 'Green Factor' to assess and reward green infrastructure in new developments. The city's biodiversity has been effectively improved, and more sustainable urban development has been promoted through this program. Melbourne has integrated green infrastructure at multiple scales to demonstrate how cities can address ecological challenges and improve the quality of life for its residents (Graells-Garrido et al., 2021; Shoina et al., 2024).

3.3. Portland: Integrating Green Infrastructure for Climate Resilience

Portland is well known for its holistic approach to green infrastructure, and in particular its management of stormwater and urban resilience to climate change. To address water management issues, and at the same time provide aesthetic and environmental benefits, the city has implemented green roofs, bioswales and rain gardens (Shoina et al., 2024). Such interventions lead to the decrease of the flood risk, the improvement of water quality and the improvement of the overall sustainability of the urban environment.

Additionally, Portland has increased the capacity of its urban green spaces network to counteract urban heat islands and to support climate adaptation. This has also seen the city introduce programmes around urban agriculture and community gardens for food security as well as breeding community engagement and sustainable urban life. The work of Portland, with its integrated approach to green infrastructure, shows how urban ecosystems can be used to create climate-resilient cities, while enhancing social cohesion and improving the well-being of its residents (Graells-Garrido et al., 2021; Moreno et al., 2024).

4. METHODOLOGY

Through a review-based methodology, this study explores the relationship between Green Infrastructure (GI) and the 15-minute city framework. A robust foundation for the analysis was built out in the form of a comprehensive literature search of the literature across databases including Google Scholar, ScienceDirect and Springer. Through the synthesis of scholarly literature, policy documents and case studies in urban planning, environmental design and climate adaptation, the research highlights key concepts, challenges and opportunities. To explore how GI can support the 15-minute city model, the study looks at global examples such as Paris, Melbourne, and Portland. Melbourne's "Grey to Green" project and "Green Factor" a tool for sustainable urban land use strategy are examples of initiatives. The research also evaluates emerging tools, such as GIS-based systems and participatory planning models, to mitigate equity challenges and prevent green gentrification. The social and environmental benefits of GI are evaluated, including its mitigation of urban heat islands, conservation of biodiversity, and enhancement of carbon sequestration, as well as its fostering of social interactions, reducing stress and improving mental health. These effects are quantified using ecosystem service evaluation frameworks. The study through a comparative analysis of selected cities finds best practices and scalable strategies for integrating GI into dense urban environments. This review synthesizes literature and case studies to offer actionable insights on how to optimize GI for 15-minute cities, strategies to improve ecological resilience, social equity, and to measure environmental and societal impacts effectively.

5. DISCUSSION and SYNTHESIS

Green Infrastructure (GI) integration is required for the 15-minute city model to be sustainable, resilient, and socially equitable. GI can be embedded into urban designs to address ecological challenges, such as biodiversity loss, urban heat islands and carbon sequestration, as well as promoting walkability and active mobility and healthier urban environments. For example, the creation of green corridors in Paris and Melbourne's 'Grey to Green' initiative show how GI can be used to enhance urban resilience and deliver key ecosystem services such as cooling, air purification and biodiversity conservation (Graells-Garrido et al., 2021; Moreno et al., 2024). Planning for the implementation of Green Infrastructure (GI) within the 15-minute city framework must be carefully balanced between ecological and social objectives. Accessing green spaces is fair, and critically, preventing the exacerbation of social inequalities must be ensured in underserved areas. Projects in Paris and Portland, which integrate GI at the neighborhood level, show how such projects can promote social cohesion while solving environmental issues (Khavarian-Garmsir et al., 2023). However, challenges like 'green gentrification,' require participatory urban planning, and inclusionary policies that address the needs of poor people. In densely populated cities, GI must be optimized in terms of

multifunctionality within limited spaces, so that GI can provide ecological services, such as stormwater management and biodiversity conservation, and social services, such as recreation and community engagement. you can see the expanded interconnection of green infrastructure benefits in the 15-minute city in Figure 4.

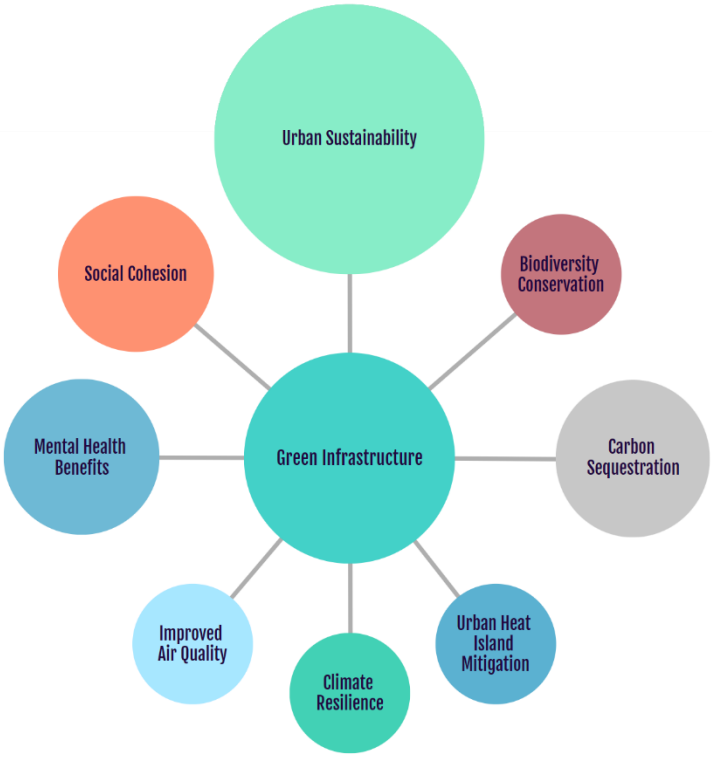

Fig. 4. *Expanded interconnection of green infrastructure benefits in the 15-minute city (Source: Authore)*

In the case of green roofs and vegetated medians not only do they manage stormwater runoff, they also enhance air quality and urban aesthetics (Pozoukidou & Chatziyiannaki, 2021). In both Portland and Paris, tactical urbanism can repurpose underutilized spaces into green areas while being both sustainable and socially inclusive (Pozoukidou & Chatziyiannaki, 2021; Abdelfattah et al., 2022). Moreover, the development of tools such as Melbourne's "Green Factor" and GIS-based assessments to guide urban planning decisions and ensure that GI interventions meet ecological and social objectives (Wang & Banzhaf, 2018). GI is crucial for urban sustainability as it can reduce the environmental footprints of cities, mitigate urban heat island effect, increase carbon sequestration, plus improve biodiversity. Concerning urban mobility and housing policies, its integration, hind of the 15-minute city model, also steers sustainability forward through diminishing car dependency and increasing the ease of access to green space. Despite these, governance fragmentation, funding constraints and the requirement for more precise ecological metrics remain significant barriers to the wider use of GI. These challenges to be overcome involve long-term planning, stakeholder multi-stakeholder collaboration, and an equity focus in urban design (Wang & Banzhaf, 2018; Hansen et al., 2017). In addition, there are still knowledge gaps in quantifying the ecological impacts of GI, in particular its potential for carbon sequestration. Advanced tools and metrics, such as GIS-based assessments and ecosystem service valuation frameworks, are required to fill these gaps and provide cities with the data they need to optimize GI interventions (Dong et al., 2024; Hansen et al., 2017).

6. CONCLUSION

This review has highlighted the transformative potential of integrating Green Infrastructure (GI) within the 15-minute city framework and shown how GI can contribute to addressing critical ecological challenges including biodiversity loss, urban heat islands (UHIs) and carbon sequestration. A few case studies on how GI has been used in cities like Paris, Melbourne and Portland to enhance urban resilience, promote social equity, and foster sustainability are presented. Key findings underscore GI's multifunctionality – it performs multiple functions, including stormwater management, creating improved air quality, and being recreational spaces – making it necessary for urban sustainability. This multifunctionality enables cities to take full advantage of the ecological, social and economic benefits of their limited urban land (Hansen et al., 2017). Cities like Paris, Melbourne and even Portland have shown that such integration of GI in urban planning is possible and has given rise to its impact. In addition, green corridors in Paris and Melbourne's "Grey to Green" initiative are examples of how GI can support urban resilience, mitigate the effects of climate change and produce healthier, more inclusive urban environments (Moreno et al., 2024; Graells-Garrido et al., 2021). Although the potential of GI is numerous, challenges for integrating the practice include governance fragmentation, funding constraints, and the potential threat of 'green gentrification' to undermine the social equity of GI ventures when not well addressed (Khavarian-Garmsir et al., 2023)

Future research can be focused on several areas to optimize GI within the 15-minute city model. However, advanced metrics and tools are needed to quantify the ecological and social benefits of GI. To assess the impacts of GI on biodiversity conservation, urban heat mitigation and carbon sequestration (Dong et al., 2024), GIS-based platforms and ecosystem service valuation frameworks should be developed. These tools enable cities to plan and evaluate better the effectiveness of GI interventions. Future research should also investigate the application and scaling of the principles and strategies of GI in compact neighborhoods to the larger scale of the urban setting where equity and sustainability are represented. To scale GI appropriately, equity and accessibility problems must be solved so that all communities experience the benefits of its integration. Critical research is also required into governance structures and policies that facilitate the successful integration of GI. The efforts to implement GI in our cities should study how cities can manage governance fragmentation and coordinate between various sectors. Analytically, this research moves beyond previous studies of GI and ecosystem services in the urban context by focusing on green gentrification and social equity in participatory planning models that employ communities in emerging and developing cities in the design and management of GI.

To ensure effective implementation of GI in the 15-minute city framework, several policy recommendations are proposed. Both urban planners and policymakers should proactively involve local communities in planning so that GI benefits the needs of all of the people in the community. A participatory approach will prevent the occurrence of unintended consequences such as green gentrification and equitable distribution of GI benefits (Khavarian-Garmsir et al., 2023). GI policies should be integrated with urban mobility, housing and adaptation to climate change strategies. With a linking of GI to these policies, cities can create an overall and more coherent urban setting with reduced car dependence, encouraged sustainable mobility and enhanced urban infrastructure resiliency. To support GI as the cornerstone of sustainable urban planning, governments should develop long-term funding mechanisms and governance structures. GI interventions are supported and maintained over time through multi-stakeholder collaborations, which include partnerships with private sector actors, community groups and non-profit organizations (Wang & Banzhaf, 2018). Policy tools such as the 'Green Factor' used in Melbourne should also be adopted by cities to encourage the take up of GI in new developments. They can promote the green design of developers and improve the ecological and social value of urban spaces (Graells-Garrido et al., 2021).

The integration of Green Infrastructure into the concept of a 15-minute city presents a strong implementation strategy for addressing the challenges of climate change, biodiversity loss and the phenomenon of heat islands in cities. Making cities more resilient, equitable and sustainable requires finding ways to optimize green space distribution and to maximize the multifunctional nature of these spaces. Yet this integration is only successful if governance, funding, and equity problems are overcome. Being able to adopt comprehensive, long-term strategies and involve communities in the planning process, cities will be more sustainable and livable following the principles of the 15-minute city model.

REFERENCES

[1] *Abdelfattah, L., Deponte, D., Fossa, G. (2022). The 15-minute city: Interpreting the model to bring out urban resiliencies. Transportation Research Procedia, vol. 60, p. 330–337.*

[2] *Ariluoma, M., Ottelin, J., Hautamäki, R., Tuhkanen, E.-M., Mänttäri, M. (2021). Carbon sequestration and storage potential of urban green in residential yards: A case study from Helsinki. Urban Forestry & Urban Greening, vol. 57, p. 126939.*

[3] *BaghaiePoor, M. (2023). The role of urban green infrastructure in 15-minute cities. Chair of Urban Structure and Transport Planning, Technical University of Munich.*

[4] *Benedict, M., McMahon, E. (2002). Green infrastructure: Smart conservation for the 21st century. Sprawl Watch Clearinghouse Monograph Series.*

[5] *Bherwani, H., Banerji, T., Menon, R. (2022). Role and value of urban forests in carbon sequestration: Review and assessment in Indian context. Environment Development and Sustainability.*

[6] *Davies, C., Hansen, R., Rall, E., Pauleit, S. (2015). Green infrastructure planning and ecosystem services: A European perspective. Land Use Policy, vol. 36, p. 300–311.*

[7] *Di Marino, M., Tomaz, E., Henriques, C., Chavoshi, S. H. (2023). The 15-minute city concept and new working spaces: A planning perspective from Oslo and Lisbon. European Planning Studies, vol. 31, no. 3, p. 598–620.*

[8] *Dong, L., Wang, Y., Ai, L., Cheng, X., Luo, Y. (2024). A review of research methods for accounting urban green space carbon sinks and exploration of new approaches. Frontiers in Environmental Science, vol. 12, p. 1350185.*

[9] *Firehock, K. (2010). Introduction to green infrastructure. Sustainable Land Use Coalition.*

[10] *Graells-Garrido, E., Serra-Burriel, F., Rowe, F., Cucchietti, F. M., Reyes, P. (2021). A city of cities: Measuring how 15-minute urban accessibility shapes human mobility in Barcelona. PLOS ONE, vol. 16, no. 5.*

[11] *Hansen, R., Buizer, M., Rall, E., Debellis, Y., Davies, C. (2015). Report of case study portraits: GREEN SURGE study on urban green infrastructure planning and governance in 20 European case studies. GREEN SURGE Project, European Union's Seventh Framework Programme.*

[12] *Hansen, R., Olafsson, A. S., van der Jagt, A. P. N., Rall, E., Pauleit, S. (2017). Planning multifunctional green infrastructure for compact cities: What is the state of practice? Ecological Indicators.*

[13] *Khavarian-Garmsir, A. R., Sharifi, A., Sadeghi, A. (2023). The 15-minute city: Urban planning and design efforts toward creating sustainable neighborhoods. Cities, vol. 132, p. 104101.*

[14] *Liu, D., Kwan, M.-P., Kan, Z., Wang, J. (2022). Toward a healthy urban living environment: Assessing 15-minute green-blue space accessibility. Sustainability, vol. 14, p. 16914.*

[15] *Liu, Y., Fan, C., Xue, D. (2024). A review of the effects of urban and green space forms on the carbon budget using a landscape sustainability framework. Sustainability, vol. 16, p. 1870.*

[16] *Luo, J., Zhai, S., Song, G., He, X., Song, H., Chen, J., Liu, H., Feng, Y. (2022). Assessing inequity in green space exposure toward a "15-minute city" in Zhengzhou, China: Using deep learning and urban big data. International Journal of Environmental Research and Public Health, vol. 19, no. 10, p. 5798.*

[17] *Moreno, C., Allam, Z., Chabaud, D., Gall, C. (2024). Implementing the 15-minute city: A case study of Paris. Climate Change and Cities, Sorbonne Business School.*

[18] *Moreno, C., Allam, Z., Chabaud, D., Gall, C., Pratlong, F. (2021). Introducing the "15-minute city": Sustainability, resilience, and place identity in future post-pandemic cities. Smart Cities, vol. 4, no. 1, p. 93–111.*

[19] *Papasa, T., Basbasa, S., Campisi, T. (2023). Urban mobility evolution and the 15-minute city model: From holistic to bottom-up approach. Transportation Research Procedia, vol. 69, p. 544–551.*

[20] *Pauleit, S., Liu, L., Ahern, J., Weiss, D. (2011). Multifunctional green infrastructure planning to promote ecological services in the city. In Green Infrastructure: Linking Landscapes and Communities (p. 33–47). Oxford University Press.*

[21] *Pozoukidou, G., Chatziyiannaki, Z. (2021). 15-minute city: Decomposing the new urban planning*

eutopia. Sustainability, vol. 13, no. 2, p. 928.

[22] *Shirgir, E., Kheyroddin, R., Behzadfar, M. (2019). Developing strategic principles of intervention in urban green infrastructure to create and enhance climate resilience in cities—Case study: Yousef Abad in Tehran. Journal of Climate Change.*

[23] *Shoina, M., Voukkali, I., Anagnostopoulos, A., Papamichael, I., Stylianou, M. (2024). The 15-minute city concept: The case study within a neighborhood of Thessaloniki. Waste Management & Research, vol. 42, no. 8, p. 694–710*

[24] *Teixeira, J. F., Silva, C., Seisenberger, S., Büttner, B., McCormick, B., Papa, E. (2024). Classifying 15-minute cities: A review of worldwide practices. Transportation Research Part A, vol. 189, p. 104234.*

[25] *Wang, J., Banzhaf, E. (2018). Towards a better understanding of green infrastructure: A critical review. Ecological Indicators, vol. 85, p. 758–772.*