SHIFTING THE DENSITY DISCOURSE: THE FUTURE OF SOFT DENSIFICATION

REPORT TO MOTT MACDONALD AND INSTITUTION OF STRUCTURAL ENGINEERS

MOTT MACDONALD

UCL SCHOOL OF MANAGEMENT SUSTAINABILITY LAB

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UCL Sustainability Lab

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ABOUT THE LAB

The UCL Sustainability Lab is a student-founded and student-led organisation, that provides a platform for collaboration between industry and academia. Founded by UCL MBA student Tom Weston in 2022, with support from Professor Paolo Taticchi, a leading expert in strategy and sustainability, the Lab has built an impactful link between business and research. Consulting Projects, Working Groups, and Industry Events have brought together organisations across the engineering and construction, finance, technology, and consulting industries, with students from UCL's 11 faculties. The Lab's operations are managed by an incredible team of 11 UCL undergraduates, graduates, and alumni. Together, these students deliver an exciting programme of projects, events, and collaborations, that bring together UCL students, societies, departments, and faculties, with a wide range of exciting industry partners.

MOTT MACDONALD AND THE SUSTAINABILITY LAB

Mott MacDonald pioneered with the UCL Sustainability Lab's first iteration working on a series of projects to address key issues in infrastructure and the built environment. As pioneers of the Lab, Mott MacDonald helped set the questions and guide the students' research, through workshops and checkpoints, ultimately reviewing the final pieces with IStructE. Mott MacDonald is looking forward to working with the Sustainability Lab for its next round of projects to work through the myriad of problems that we face as an industry and indeed society, continuing to break down complex problems through a multi-disciplinary approach.

INSTITUTION OF STRUCTURAL ENGINEERS AND THE SUSTAINABILITY LAB

This project is a response to a question originally posed by the Institution of Structural Engineers, specifically "how does the embodied carbon impact of building taller compare with other metrics?". We were delighted to be asked to review the research during its development, and hope that the industry finds this output useful in progressing this important debate.

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“The work the lab did around the lenses of the tall vs sprawl problem was engaging and neatly broke down the multi-facted nature of the problem”

Scott Kent
Stakeholder Manager to the Lab

“The lab came to us with open minds and really delved into the problems we set them. Their enthusiasm and professionalism meshed well with our team and gave us much to think about.”

Toby Robinson
Collaborator with the Lab

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INSTITUTION OF STRUCTURAL ENGINEERS

Will Arnold
Fellow and staff member

“This work explored an important yet under-researched area of the built environment and produced more questions than answers – highlighting its necessity. I hope that others can built on this, to better understand and develop the body of knowledge. I look forward to continued IStructE collaboration with the UCL Sustainability Lab moving forwards.”

NOTE

Please note, this report is authored by UCL Students and not UCL Faculty. This is a student-led initative.

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ABSTRACT

The current research report summarises the findings of a comprehensive, multidisciplinary project carried out by the UCL Sustainability Lab in association with Mott McDonald and the Institution of Structural Engineers. The project focuses on three key objectives targeting knowledge exchange, understanding success factors and existing gaps, and furnishing suggestions concerning sustainable built environments and urban ecosystems.

Firstly, the study targeted to bridging knowledge between disciplines within the built environment sector. In this process, key stakeholders involved or affected by these issues are identified and prominent research and policy areas that discuss the same are illuminated, aiming at promoting a more collaborative and educated approach to building sustainability. The second goal was to identify the characteristics of successfully livable and sustainable urban ecosystems. Several influencing elements were found after a thorough assessment of the available research and practices. However, this deep dive also revealed substantial gaps and challenges. Significant barriers to research, industry concretization, and policy implementation were identified, ranging from data collection and processing challenges to limited space, zoning regulations, local and institutional capacity building, politics, and the lack of financial and governmental incentives for industry. Finally, this research aspires to establish a comprehensive guide that offers insightful recommendations, seamlessly integrating urban development with sustainability and livability to foster balanced growth.

Three key concepts that are frequently brought up in this discourse are discussed: the optimal height of buildings, the sustainability of the built environment and the idea of urban densification. Acting both as a limitation of this study and an opportunity to demonstrate the need for further collaboration between sectors, the lack of alignment in definitions of these concepts truly highlights the gap in literature and practice.

The findings of this study provide a strategic road map for future work in the construction industry, paving the way for a more resource-aware, urbanised, and sustainable future. They insist the construction sector adjusts due to these discoveries by highlighting the significance of an integrated, interdisciplinary approach to sustainability in built environments. By conducting this analysis, we hope to help foster a culture of harmonisation of these interconnected concepts, and a holistic approach to sustainability in cities and in the construction industry and urban planning domain.

Considering that planning transformational and mega-infrastructure projects requires multi-scale and cross-sectoral collaboration, we aim to provide more insight both on structural and architectural solutions, as well as the mitigation of environmental and social impacts. In other terms, adopting a holistic approach to the built environment in a way that situates policy and planning more clearly, enables more fruitful interventions and change. This research report intends to identify and consolidate concerns, critiques and case studies on the urban densification discourse, the built environment developments, and urban ecosystems.


“THE QUESTION IS NOT
WHETHER DENSITY IS
BAD OR GOOD,
BUT RATHER
AT WHAT PRICE AND HOW”

1. CONTEXT

Today, 55 percent of the world's population lives in urban areas, a proportion that is expected to reach 68 percent of a constantly growing population approaching 10 billion by 2050.[1] As cities grow and become increasingly complex systems of interconnected ecologies and networks[2], one of our most serious concerns should be how they expand.

Considering, in parallel, the extant threat of climate change and the fact that the built environment accounts for more than 40 percent of the world emissions[3], the pursuit of the optimum sustainable densification approach should be prioritised. However, sustainability in a system as complex as a city, will never be straightforward and various multifaceted and even counterfactual aspects should be considered.

The question is not whether density is bad or good, but rather at what price and how. Planners, developers, and decision-makers need to consider what higher density should look like, what it will mean for the people living in cities, and how it can be as sustainable as possible.[4] Recently, the issue of urban density has become a highly debated topic.[5] [6] Housing demands – needs, choices, and aspirations – are a growing pressure point on urban developments. This has been particularly exacerbated by the COVID-19 pandemic – with social isolation, the need for human and nature connection in

1.1 CONCEPTS

Sustainable Built Environment Ecosystems

There are several different ways of describing sustainability in the literature and sources, but the initial principles and meaning are the same as that of providing a pleasant life from the environmental point of view, friendly to nature, cost-effective and egalitarian across all pillars that are of great importance for climate, society, and economy without compromising future generations' ability to fulfil their own needs.[7] [8] [9] [10] Using Al-Kodmany's guiding framework to sustainable urban density and the built environment, the '3 Ps' (*people, profit, planet*) has been applied when analysis the body of evidence in the bibliometrics analysis, literature review and cases studies. These pillars or dimensions are also expressed by the '3Es' of equality, economics, and ecology or what is known as the triple bottom line. The authors suggest a guiding framework to organize the many issues related to tall building developments, built around 'sustainability'. Sustainability is a concept that applies to all levels of buildings development, design, and planning, from the choices of structural systems and finishing materials to the relationships of indoor and outdoor spaces to integration with the larger urban context.

1 United Nations Department of Economic and Social Affairs (2018) 68% of the world population is projected to live in urban areas by 2050, says UN. United Nations News. Retrieved from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
2 Neuman, R. (2022) *Sustainable infrastructure for cities and societies.* Routledge.
3 International Energy Agency (2022) Buildings. IEA. Paris.
4 Short, M. and Livingstone, N. (2020) Planning for densification and housing in London: Urban design and real estate agendas in practices, in *Critical Dialogues of Urban Governance, Development and Activism: London and Toronto*. Retrieved from https://discovery.ucl.ac.uk/id/eprint/10115557/1/Critical-Dialogues-of-Urban-Governance-Development-and-Activism.pdf
5 OECD (2018) Rethinking Urban Sprawl: Moving Towards Sustainable Cities. OECD. Retrieved from https://www.oecd.org/environment/tools-evaluation/Policy-Highlights-Rethinking-Urban-Sprawl.pdf
6 Behnisch, M., Krüger, T., and Jaeger, J. A. G. (2022) Rapid rise in urban sprawl: Global hotspots and trends since 1990. PLOS Sustainability and Transformation. https://doi.org/10.1371/journal.pstr.0000034
7 Al-Kodmany, K. (2018) The Vertical City: A Sustainable Development Model. WIT Press. Al-Kodmany, K. (2014), Green Towers and Iconic Design: Cases from Three Continents. International Journal of Architectural Research 8: 11–28. doi:10.26687/archnet-ijar.v8i1.336.
8 Newman, P. (2001) Sustainability and Cities: The Role of Tall Buildings in This New Global Agenda. Tall Buildings and Urban Habitat 22: 75–105.
9 Sassi, P. (2006) *Strategies for Sustainable Architecture*. New York: Taylor & Francis.
10 Jin, X., G. Zhang, J. Zuo, and S. Lindsay (2013) Sustainable High-rise Design Trends– Dubai's Strategy. Civil Engineering and Architecture, 1: 33–41.

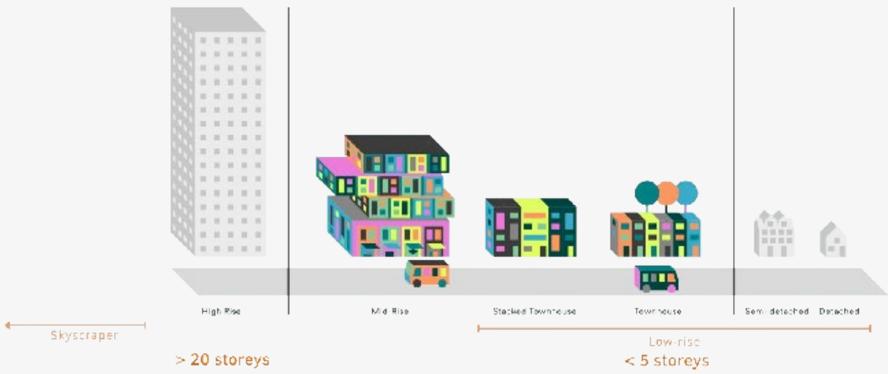
Density

Urban density is defined as the ratio of the total population of a city and its total area. It is the most commonly used measure in population statistics. The OECD considers high urban density as more than 1, 500 inhabitants per km^2.[11] In the UK, particularly in housing and planning policies, the government measures the average density by the number of dwellings within one hectare, but there is various means of measuring living space (population vs. dwelling). For example, the UK is the third most densely populated country in the EU, after the Netherlands and Belgium; however, it has a relatively low number of people per dwelling (2.3) compared with the rest of Europe (e.g., Spain, 3; Ireland 2.9). Only Denmark and Sweden (2.1), the Netherlands and Finland (2.2) are lower.[12] Density is a measure: it does not imply urban form or design.

In some cases, the desire for high-density development has been used to support proposals for tall buildings. However, it is clear that tall buildings represent only one possible model for high-density development. While tall buildings with a large total floor area have a correspondingly large impact on their location in terms of activity and use, this can be equally true of large and dense developments with low and mid-rise buildings.[13 14] In addition to the building height and layout, the overall density of a development is also affected by the proportion of public space between the buildings. Indeed, the same density can be achieved through tall towers with a fair amount of space between them or a more packed mid-rise solution.[15]

For the purpose of this project, we have settled on foundational definitions and typologies of building – provided and agreed by and with our research partners (**Figure 1**). Many definitions across the globe, governments and engineers are being used to define building height categories. According to our research, these chosen categories also correspond to the majority or average range of building heights used in Europe or North America. We will particularly use the following categories: high rise (over 20 storeys); mid-rise (5 to 20 storeys); and low-rise (5 storeys or under).

Figure 1. Building Height Typologies



11 OECD (2018) Rethinking Urban Sprawl: Moving Towards Sustainable Cities POLICY HIGHLIGHTS. OECD. Retrieved from https://www.oecd.org/environment/tools-evaluation/Policy-Highlights-Rethinking-Urban-Sprawl.pdf
12 Williams, K. (2009) Space per person in the UK: A Review of densities, trends, experiences, and optimum levels. Land Use Policy, 26. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0264837709001124
13 Greater London Authority (2016) London Plan density research – Lessons from higher density development: Report to the GLA. Retrieved from https://www.london.gov.uk/sites/default/files/project_2_3_lessons_from_higher_density_development.pdf
14 Sim, D. (2019) *Soft City: Building Density for Everyday Life.* Island Press.
15 Ibid.

Soft density

Soft density is referring to high-density and mid-rise building urban grid patterns, coupled with retrofits of existing buildings, has been praised and adopted across the globe.[16 17 18 19] Whilst the term *soft densification* is new, the concept of densifying urban environments through small scale changes is not entirely novel, whether it is termed 'intensification', 'consolidation', 'urban compaction' and what has been described as re-urbanisation through the 'return to the city'.[20] Neighbourhoods in cities like the Plateau-Mont-Royal in Montréal (Canada), 7e Arrondissement in Paris, or Manhattan in New York City (U.S.A.) are successful examples of this type of density pattern. While some argue that higher buildings are needed to accommodate our growing population, maximise land use and decrease transportation and infrastructure needs, others are concerned about their impact on the quality of life, social cohesion, and the environment.[21 22 23 24] Research has shown that high-rise buildings can contribute to feelings of alienation, as residents may have limited opportunities to interact with their neighbours.[25] With mid-rise high-density neighbourhoods, we avoid losing that sense of human scale community and healthy social interactions without extensive horizontal city sprawling, as defended and praised by Jan Gehl, a Danish architect, and urban designers.[26]

1.2 RESEARCH QUESTIONS

- What are the characteristics and impacts of these urban interventions on the environment, economy, and social fabric of a city?
- What is the optimal density and height of our built environment according to these indicators?

16 Chakrabarti, V. (2022) A vision of sustainable housing for all of humanity. *Ted Talk.* Retrieved from https://www.ted.com/talks/vishaan_chakrabarti_a_vision_of_sustainable_housing_for_all_of_humanity?language=en
17 Gehl, J. (2010) *Cities for People.* Island Press.
18 Bryson, K. & Allen, N. (2021). Defining medium-density housing. *Technical and Research Study Report by BRANZ.* Retrieved at 10.13140/RG.2.2.21173.40161
19 Gehl, J. (2019) *Soft City: Building Density for Everyday Life.* Island Press.
20 Dunnning, R., Hickman, H. and While, A. (2020) Planning control and the politics of soft densification. *Town Planning Review,* 91 (3). pp. 305-324. Retrieved from https://eprints.whiterose.ac.uk/155876/
21 Prezza, M.; Amici, M.; Roberti, T.; Tedeschi, G. (2001) Sense of community referred to the whole town: Its relations with neighbours, loneliness, life satisfaction, and area of residence. *Journal of Community Psychology* 29, 29–52
22 Romanova, E. (2017) Increase in Population Density and Aggravation of Social and Psychological Problems in Areas with High-Rise Construction. *E3S Web of Conferences 33.* Retrieved from https://www.e3s-conferences.org/articles/e3sconf/pdf/2018/08/e3sconf_hrc2018_03061.pdf
23 Story, L. and Saulfeb, S. (2015) Stream of Foreign Wealth Flows to Elite New York Real Estate. *The New York Times.* Retrieved from https://www.nytimes.com/2015/02/08/nyregion/stream-of-foreign-wealth-flows-to-time-warner-condos.html?_r=0
24 Welege, N. and Kumaraswamy, M. (2022) Engaging Stakeholders to Overcome the Common Constraints for Delivering Low Carbon Buildings in High-Rise High-Density Cities. *Journal of Construction Engineering and Management (149), Issue 1.* Retrieved from https://ascelibrary.org/toc/jcemd4/149/1
25 Larcombe, Danica-Lea, Eddie van Etten, Alan Logan, Susan L. Prescott, and Pierre Horwitz. 2019. "High-Rise Apartments and Urban Mental Health—Historical and Contemporary Views" *Challenges* 10, no. 2: 34. https://doi.org/10.3390/challe10020034.
26 Gehl, J. (2010) *Cities for People.* Island Press: Washington, DC, USA.

2. METHODOLOGY

The research initiated with a structural engineering perspective of finding optimal height of buildings in cities – assessing the 'Tall vs. Sprawl' dilemma.[27] Rapidly, it was evident that interconnected concepts floating around the built environment and urban density were strongly linked to sustainable standards and indicators of success, and highly dependent on the context (e.g., geographic location, weather, zoning laws, heritage regulations, cultural norms, etc.). In that sense, a holistic vision of the question was approached through a short rapid evidence assessment, and reviewing key pieces of the literature.

3. RAPID EVIDENCE ASSESSMENTS

We conducted a two-step approach rapid evidence assessment. When conducting the first bibliometrics analysis, the results observed *(please see first note below)* are disproportionately falling into the subject areas of social science, engineering, and environmental science domains of study economic studies, amongst others, on the topic. From the results of our second assessment *(please see second note below)*, we can suggest that by adding the search term 'tall building', referring to the built environment directly, the main subject area was from engineering studies. We also found in second round, that the number of publications has increased since the 1970s. However, it is after the 2000s that the number of publications augmented drastically, mainly due to the boom of new technologies that permitted such new constructions. Countries that published the most publications on the topics were from US, UK, and China. Indeed, there is a great interest, in the last decade, in analysing and learning from Chinese high-rise developments.

After the rapid literature review, the main stakeholders involved were mapped according to the level of impact on the main indicators found in the literature review (**Figure 2**). This step facilitated a more complete perspective on this issue. Based on the selected key pieces of literature, key parameters that influence the livability of urban ecosystems and the sustainability of the built environment in cities were scoped. Furthermore, in order to properly illustrate and test these parameters, a comparative case study analysis was conducted. Due to the availability and comparability of data at the local level, two of the biggest metropolises in Europe were selected: London and Paris. This analysis allowed to confirm claims and arguments made in the literature and helped to move forward in captivating three key determinants to consider when thinking about urban densification. The report concludes with a section on **Key Recommendations** and potential avenues for further research, aimed at guiding future actions within the construction industry and informing decisions made by urban planners.

27 Willis, C. (2014) The Logic of Luxury: New York's New Super-Slender Towers. CTBUH Research Paper, Council on Tall Buildings and Urban Habitat, pp. 357–364.

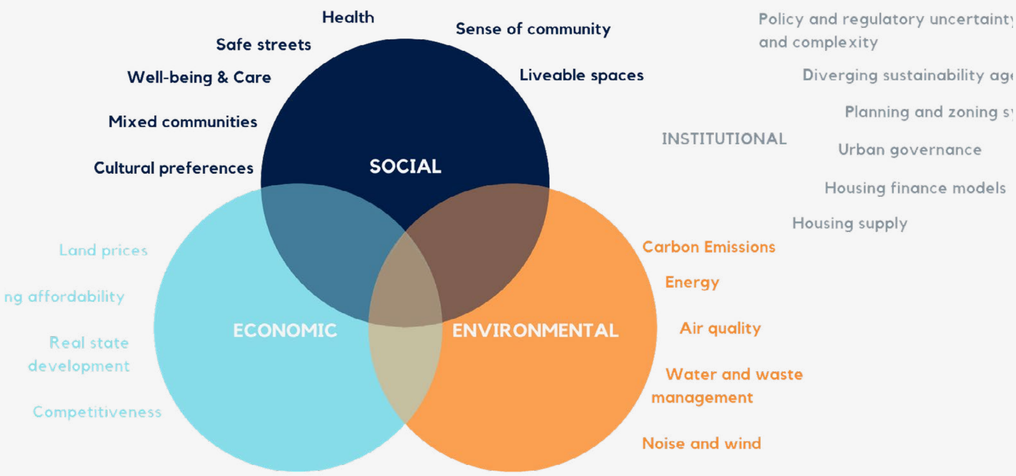
Notes
1. Conducting a bibliometrics analysis using the search terms "(urban OR city) (urban AND dens) (built AND environment)", we found 3,413 relevant documents.*

2. Conducting a bibliometrics analysis using the search terms (city AND density AND "tall building"), we found 236 relevant documents.

4. PARAMETERS ASSESSED

After the completion of the literature review, we mapped the main indicators discussed in key papers in the urban density and sustainable built environment discourse (**Figure 2**). This mapping of indicators is inspired on Westerink approach to analysing this intricate concept, organising it into four distinct categories.[28]

Figure 2. Mapping of key indicators influencing the sustainability of the built environment and urban ecosystems.



28 Westerink, J.; Haase, D., Bauer, A.; Ravetz, J.; Jarrige, F. & Aalbers, C. (2013) Dealing with Sustainability Trade-Offs of the Compact City in Peri-Urban Planning Across European City Regions, European Planning Studies, 21:4, 473-497, DOI: 10.1080/09654313.2012.722927

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4.1 FIRST SCOPING OF THE PARAMETERS

Two steps approach
When mapping the key indicators impacting the density and sustainability discourse in the built environment sector (**Figure 3**), we found first and foremost eight most-referred indicators in our literature review, which will be briefly detailed below (Section 4.1). The second step of our approach was to narrow down, according to our findings, the most impactful indicators in Section 4.2.

Eight parameters were selected for the first step of the research: embodied carbon; operational energy; grey infrastructure; transportation; blue and green infrastructure; well-being; local economic growth; and politics. These were selected based on the key pieces of evidence, the availability of data, the comparability with other studies, and principally, the qualifiable correlation significance to our research questions, and narrowed subsequently to three quantifiable key indicators (Section 4.2) to analyse the sustainability of urban ecosystems and built environment.

Some concepts considered

Grey infrastructure
Grey infrastructure, includes gutters, drains, pipes, and retention basins, is the conventional stormwater infrastructure seen in the built environment. The consensus indicates that sprawling low-density development occupies more land surface for accommodating the same population, thus generates the need for longer highways and streets, increasing pipelines' length and other facilities that subsequently burden the environment with carbon emissions and resources consumption for construction and maintenance.[29]

Well-being
Many factors are influencing the well-being of residents in a local area, such as the global health indicators or socio-economic status. Although high-rises potentially offer the benefits of both urban and suburban life because of the proximity to urban amenities[30], if poorly designed, living in tall buildings can contribute to emotional stress and isolation due to the lack of social interactions and outdoor green and social spaces.[31 32] Adding to this, the concept of 'densities of care' emerges in relation to an ultra-dense built environment. This notion illustrates how crowds, which might appear dispersed and uncoordinated, can enhance relational ethics through their interactions.[33] Indeed, physical proximity engendered by high-density built form did little to encourage community.[34]

Politics
Politics shapes how and when cities adopt and deploy densification policies and how well it is received by the communities. Facing climate change, urban densification strategies are being viewed as a favourable strategy for ensuring environmental sustainability, reducing the ecological footprint, promoting economic vitality and providing affordable housing.[35] However, urban gentrification, escalating housing prices, struggles over urban land use, paired with the living cost crisis, all contradict these iterations of urban density.[36] Political institutions and decision-makers play an important role in balancing different interests, set clear and effective regulations and granting experts more authority to approve or deny proposed buildings based on their fit within the existing urban context also considering the concepts above.

29 Wood, A., & Du, P. (2017). Dense Downtown vs. Suburban Dispersed: A Pilot Study on Urban Sustainability. International Journal of High-Rise Buildings, 6(2). https://doi.org/10.21022/ijhrb.2017.6.2.113
30 Al-Kodmany, K.; Ali, M.M. (2013) The Future of the City: Tall Buildings and Urban Design; WIT Press: Southampton, UK.
31 Prezza, M.; Amici, M.; Roberti, T.; Tedeschi, G. (2001) Sense of community referred to the whole town: Its relations with neighbouring, loneliness, life satisfaction, and area of residence. Journal of Community Psychology 29, 29–52
32 Romanova, E. (2017) Increase in Population Density and Aggravation of Social and Psychological Problems in Areas with High-Rise Construction. E3S Web of Conferences 33. Retrieved from https://www.e3s-conferences.org/articles/e3sconf/pdf/2018/08/e3sconf_hrc2018_03061.pdf
33 Chen, H.-Y. (2020) Densities of care. Urban Geography 41 (10), 1302-1309, DOI: 10.1080/02723638.2020.1850045
34 Blanc, F.; Scanlon, K. and White, T. (2020) Living in a denser London: How residents see their homes. *LSE Cities.*
35 Angelo, H., and Wachsmuth, D. (2020) Why does everyone think cities can save the planet? Urban Studies 57(11): 2201–2221.
36 Heinonen J, Jalas M, Juntunen JK, et al. (2013) Situated lifestyles: II. The impacts of urban density, housing type and motorization on the greenhouse

"WE CAME DOWN TO THREE KEY INDICATORS INFLUENCING THE SUSTAINABILITY OF URBAN DEVELOPMENTS:
(1) GREEN INFRASTRUCTURE
(2) URBAN MOBILITY
(3) EMBODIED AND OPERATIONAL CARBON."

4.2 KEY PARAMETERS

According to the clusters described above, to assemble essential sustainability indicators to consider in building sustainable and liveable environments, the current study primarily focused on: **green infrastructure**; **urban mobility** and **embodied and operational carbon**.

1 - Green infrastructure

According to the research conducted for the scope of this report, green infrastructure is one of the main parameters that has a significant effect on sustainability in the built environment, urban ecosystems, and its residents. A network of deliberately planned natural and semi-natural spaces with additional environmental elements is known as **green infrastructure** or **green space**, primarily composed of unsealed, permeable, soft surfaces including trees, and water[37], like parks, community gardens, and nature conservation areas, and private green space like backyards and buildings complex common areas.[38]

Access to green space evaluation is a complex procedure that considers the availability of green space, the proportion of green space per person and their accessibility (e.g., in London, only 18 percent of London is officially publicly accessible green space[39]). Access to green spaces is primarily concerned with how close green spaces are to a resident's home, but it also considers accessible public transportation routes. On the other hand, the quantity of green space per capita is a measurement of the amount of green space in relation to the population, giving insight into how well a region is doing in terms of providing enough greenery for its residents. Finally, their availability is evaluated by examining their number, size, and distribution as well as the amenities they offer, their hours of operation, and the degree to which they meet the needs of various community segments.

In terms of green spaces' relation to height of the building environment, the careful integration of both high and low-rise buildings is an essential aspect of sustainable urban planning, fostering a healthier and more livable urban environment. Some researchers suggest that high-rise buildings have decreased residents' access to nature and green spaces and increased their separation from them.[40] On the other hand, in some cases, denser areas can increase access to nature by reducing the average commuting time if the distance to green spaces is high, while the land saved due to denser arrangement can be transformed to extensive virgin green space.[41] A recent study from the London School of Economics suggest that land saved from urban development by post-1975 tall buildings contruction is over 80 percent overed in vegetation.[42]

37 James, P., Tzoulas, K., Adams, M. D., Barber, A., et al. (2009). Towards an integrated understanding of green space in the European Built Environment. Urban Forestry & Urban Greening, 8(2), 65–75. https://doi.org/10.1016/j.ufug.2009.02.001
38 Wolch, J.R., Byrne, J. & Newell, J.P. (2014) Urban green space, public health, and environmental justice: The challenge of making cities "just green enough. Landscape and Urban Planning, 125. doi:10.1016/j.landurbplan.2014.01.017.
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40 Elsadek, M., Liu, B., & Xie, J. (2020). Window view and relaxation: Viewing green space from a high-rise estate improves urban dwellers' wellbeing. Urban Forestry & Urban Greening, 55, 126846. https://doi.org/10.1016/j.ufug.2020.126846
41 Wolff M and Haase D (2019) Mediating Sustainability and Liveability—Turning Points of Green Space Supply in European Cities. Front. Environ. Sci. 7:61. doi: 10.3389/fenvs.2019.00061
42 Centre for Economic Performance (2023) The skyscraper revolution: Global economic development and land savings. Retrieved from https://cep.lse.ac.uk/pubs/download/dp1959.pdf

KEY PARAMETERS

Green infrastructure

The strategic use of green spaces as networks of natural lands, working landscapes, and other open spaces to conserve ecosystem values and functions, is considered to provide associated benefits to human populations by directly impacting the community's **well-being**.[43] Even though well-being can be a subjective metric, happiness, health and satisfaction are crucial components. Green spaces can function as attractive public places for gathering, socialising, relaxing and playing, fostering the sense of community, mitigating isolation and upgrading overall mental health.[44] The system of green (land) and blue (water) spaces enhances the environment and air quality, connectivity, and state of natural areas, as well as the standard of living of residents.[45] In terms of health, epidemiological research has shown a link between access to green space and longevity, as well as between exposure to the natural environment and subjective well-being like happiness.[46]
Local infrastructure improvements can also support biodiversity in human-dominated areas[47], whereas the familiarisation with nature sensitises people, raises awareness of climate change and incentivises them to take action for environmental preservation.[48 49]

More globally, planning for green and blue infrastructure has been proven to be a useful method for achieving social, economic, and environmental goals and in many instances, they can decrease reliance on grey infrastructure, which can be more difficult to create and maintain, more expensive to build, and potentially harmful to the environment and biodiversity.[50]

43 Neuman, M. (2022) *Sustainable infrastructure for cities and societies.* Routledge.
44 Haaland, C. & van den Bosch, C.K. (2015) Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry and Urban Greening.*14 (4). doi:10.1016/j.ufug.2015.07.009.
45 Wolch, J.R., Byrne, J. & Newell, J.P. (2014)
46 Jennings, V., Larson, L., & Yun, J. (2016). Advancing Sustainability through urban green space: Cultural Ecosystem Services, equity, and Social Determinants of Health. International Journal of Environmental Research and Public Health, 13(2), 196. https://doi.org/10.3390/ijerph13020196
47 Haaland, C. & van den Bosch, C.K. (2015)
48 Chawla, L. (1999) Life paths into effective environmental action. *Journal of Environmental Education.* 31 (1). doi:10.1080/00958969909598628.
49 Phillips, R., Abbas-Nazari, A., Tooze, J. & Gant, N. (2020) Designing for active engagement, enabling resilience and fostering environmental change. *Journal of Design, Business and Society.* 6 (1). doi:10.1386/dbs_00004_1.
50 European Commission (2021) Supporting policy with scientific evidence. Green and Blue Infrastructures. European Commission. Retrieved from https://knowledge4policy.ec.europa.eu/glossary-item/green-blue-infrastructures_en

2 - Urban mobility

According to the literature, in low-density areas, individuals find themselves farther away from workplaces, amenities, as well as economic and cultural hubs.[51 52 53 54 55] These developments often result in a higher-emissions due to longer commuting times to city-centre (often workplace) which dicentivise people from using any form of active mobility.

But design and planning impacts how we envision urban mobility patterns. If planned with a transit-oriented development approach, densely populated areas featuring tall and medium-height buildings can enhance the connectivity of networks for active mobility, including the design of intersections, streets, or squares.[56] Spatial structures and the built environment do impact how we move in space and therefore our carbon footprint.

The density of public transportation including buses, tube lines and bike sharing stations, is considerably lower moving towards the more suburban areas, compared to central boroughs, thereby promoting greater reliance on cars. This means that sprawling development either leads to not-sufficiently accessible neighborhoods, where cars are the most popular form of transportation way, or new infrastructure facilities are required - increasing emissions and resources consumption, to achieve acceptable operational and maintenance standards. Indeed, dense, well-connected, urban developments have smaller carbon footprints as journeys are shorter, therefore require less energy. Data from the *UK National Travel Survey* shows that in areas classified as 'urban conurbation', the average distance travelled by car is 2,000 miles a year, but this rises to 4,700 miles for areas classified as rural town and fringes.[57]

Residential areas nearer to city centers typically boast reduced carbon footprints - the case of London (United Kingdom)

Londoners have different carbon footprints depending on where they live; and these differences are mainly caused by transport-related CO_2. Islington and Hackney boroughs – denser and closer to the city centre – have relatively low levels of transport emissions per capita (below 0.5 tonnes of CO_2 per year). Conversely, more suburban areas like Havering and Hillingdon can experience transport emissions that are 3-4 times higher than those in the aforementioned boroughs.[58]

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3 - Embodied and Operational Carbon of the Built Environment

The environmental footprint, in the context of the built environment, is assessed considering two fundamental aspects; embodied energy or carbon and operational carbon emissions. **Embodied carbon** refers to the greenhouse gas emissions – measured in carbon dioxide equivalent - that are associated with the entire lifecycle of a building's materials. This includes the carbon dioxide equivalent produced during the extraction, manufacture, transportation, assembly, replacement, and end-of-life disposal or recycling of these materials. On the other hand, **operational carbon** refers to the amount of energy consumed by a building during its use phase to maintain a comfortable and functional environment for its occupants, including energy used for heating, cooling, lighting, and powering appliances and systems within the building.

Embodied carbon is considered a feature sensitive to the characteristics of each building, including the type of materials and the construction system deployed, the distance of the raw materials from site and the way they are being transported. However, it has been observed that embodied carbon per capita is correlated with city density and average height of structures.

To begin with, vertical development by constructing higher-rise buildings imposes additional structural burdens. The heightened mass necessitates stronger foundations to support increased weight, placing greater loads on the ground, while the lower levels must endure the added pressure exerted by the extra stories above. Moreover, as buildings reach certain heights, the presence of powerful winds becomes a significant concern, mandating more heavily reinforced structures.[59]

These factors generate an 'embodied carbon premium of height'. Compared to soft density alternatives, high-rise typologies rely on vast resources input as tall buildings tend to be bulky, and more structurally demanding, requiring elements of increased size and more carbon-intensive materials like concrete, steel reinforcements and aluminum.[60] [61] [62] Glazed cladding systems - commonly used for high-rise structures - typically require replacement before the structure's end-of-life[63], and greener materials like alternative concrete and timber, that would lead to a saving of 1 $MtCO_2e$ annually, cannot be – at least for now - widely applied in taller buildings. [64]

More specifically, data from an extensive study from Edinburgh Napier University indicated that high-density and low-rise buildings development seems to be the less carbon-intensive solution, estimated to halve CO_2 emissions/per capita over a 60-year life cycle.[65] The materials used for the façade (aluminum and glass for modern high-rise buildings) seem to be the characteristic that mainly incite this considerable difference. The study concludes that high-density and low-rise urban development strategies are the optimum solution in terms of CO_2 emissions (*see note below*).

59 Pomponi, F., Saint, R., Arehart, J.H. et al. Decoupling density from tallness in analysing the life cycle greenhouse gas emissions of cities. npj Urban Sustain 1, 33 (2021). https://doi.org/10.1038/s42949-021-00034-w
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63 Sturgis S. (2020), The glasshouse effect, RICS Construction Journal: February-March 2020. *RICS Construction Journal*. Retrieved from https://issuu.com/ricsmodus/docs/construction_journal_feb-mar_2020_interactive/24
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Note: As identified in section 5, Paris' 7e Arrondissement has a high-density and low to mid-rise buildings due to well-preserved areas, robust regulation, and zoning laws, coupled with good thermal insulation – especially buildings constructed before 1939 - where the thermal properties of older buildings are generally of a heavy structure with thick walls.

As for the operational carbon, there is conflicting evidence. Considering the building physics, the building shell is the part more exposed to the outer weather conditions. Regardless of the insulation and thermal mass capacity, heat will be transferred between the out- and indoor environment, with the envelope being the primary heat sink. As the form factor (ratio of envelope to floor area) diminishes, decreased heat loss is observed (less leakages and thermal-bridging), allowing thermal convenience to be achieved with less carbon on a per meter-square basis. If individual dwellings exhibit a comparatively high form factor than an apartment in higher-rise structures. But high-rise buildings are expected to demonstrate a less favorable form factor compared to mid-rise constructions. The form factor is primarily influenced by the compactness, improved for mid-rise buildings but not necessarily accordingly with building height. And taller buildings potentially provide ample access to sunlight and wind, which can be utilised for the efficient integration of solar panels and photovoltaic cells.[66] Assuming also high-density, reduced heat exchange with the surrounding environment should be considered as an alleviating mechanism for heating/cooling needs.[67] An extensive global study reached the conclusion that higher urban density is equally impactful as energy efficiency improvements in building heating and cooling when it comes to achieving energy savings.[68]

The higher glasing proportion in taller buildings creates higher heat loss/gain due to material being a less effective insulator than masonry, requiring increased energy for heating or cooling. Taller building also face stronger winds and lower temperatures, necessitating more heating. Though they may receive more sunlight and less overshadowing, this can lead to higher cooling energy needs, while strong winds limit natural ventilation, contributing to higher operational carbon emissions.[69] High-rise buildings exert a negative effect on the thermal microclimate of city centres, especially during the warmest months. The geometry of the buildings alters the airflow patterns, hindering the cleaner and cooler air circulation and increasing the air humidity. The excessive radiation absorbed by the shell

Concluding a straightforward notion might be challenging, given the numerous factors influencing the operational carbon component of the carbon footprint. A middle ground can be identified in mid-sized structures that present an optimal balance; lower-rise structures suffer from inefficient form factors, while larger ones may detrimentally affect the microclimate and result in inefficient layouts and overcomplicated services. This is called **soft density**.

But it is worth mentioning that even for this balanced solution, the carbon footprint is remarkably high throughout its lifetime (over 2400 $kgCO_2/m2$)[75], which means 288 $tnCO_2$ for a typical family (considering 30m^2 per person). In 2022, the sector's carbon emissions reached 10 gigatonnes of CO_2 equivalent – 5 percent over 2020 levels and two per cent over the pre-pandemic peak in 2019.[76] One of the tools at our disposition to mitigate this burden is by restricting the construction of new buildings whenever feasible, seizing every opportunity for retrofitting, enhancing energy performance, and extending the lifespan of existing structures.

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5. CASE STUDIES

5.1 SELECTION OF CASE STUDIES

Borough of Islington, London, United Kingdom

7e Arrondissement Paris, France

Royal Borough of Kingston upon Thames, London, United Kingdom

London was the first city selected to highlight the differences between tall and sprawl, given its architecture, planning diversity, large population, and its economic and social stratification. The availability of public data and London's international character were important elements for choosing this city as a case. In particular, the **Borough of Islington,** located near to central London, holds a high-density area with relatively mid- to high-rise buildings. In contrast, the **Royal Borough of Kingston upon Thames**, a quieter area which is situated in the outer London, has notably lower density and predominantly low-rise buildings. A comparable area was searched to validate the findings and add a '*golden mean*' approach of a high-density and low-rise buildings development (**Table 1**).

7ᵉ Arrondissement (Paris, France), as its European countapart, constitutes a compatible option in terms of geospatial, cultural and especially data availability factors. It is worth noting that our study is comparing three case studies from the Western world. We are conscious that this is a limitation as it lacks representativeness. The findings may not be applicable to all cases due to variations in conditions, such as weather, politics, socio-economic factors, technology, and other variables. The lack of comparability between these factors across different regions undermines the generalisability of the key findings to broader contexts.

The Case of Islington: Example of Mid-rise Developments

In the 2018 Borough of Islington's study report on tall buildings[78], they mention that recent residential developments as well as historic examples of some Edwardian Mansion Blocks show that residential densities of 200 to 450 units per hectare can be delivered with buildings of less than 10 storeys with a common height range of six to eight storeys.

Table 1. Boroughs' characteristics in terms of density, building stock, facilities and environmental and socioeconomic aspects

Boroughs	Density (people/ km2)	Average Number of Storeys	Average Rent (pounds/ m2)	Home ownership (%)	Social Housing (%)	Unem-ployment rate (%)	Schools (per km2)	Green space/ habitants (m2)	Air quality (µg/m3)
Islington	14.591	5-25 (middle-high)	40-50	27	9	3.2	5.25	7.48	47
7e Arrondis-sement	11,953	3-8 (low)	30	41	4	6.7	6.78	6	26.3 (Paris)
Kingston Upon Thames	4,820	middle-low	30-40	62	4	2.3	1.73	54	34

5.2 CASES ANALYSIS

Comparing London boroughs, that have similarities regarding microclimate, building's age and energy costs/regulations, the Royal Borough of Kingston upon Thames area has the highest operational energy per dweller, as suggested in **Table 2**, validating the literature consensus that higher buildings and more compact arrangements tend to be more energy-saving. On top of that, buildings are not exceptionally tall in Islington to experience increased heating energy needs due to the exposure to winds and lower temperatures or lack of overshadowing as occurs in other cases in the literature, hence the first mechanism dominates.

The data discrepancy concerning energy consumption in the 7^{e} Arrondissement can be partially attributed to the increased summer temperatures in Paris, leading to heightened demand for air conditioning. However, the marginal average temperature difference between the two cities does not fully justify the variance in energy needs.[79] A more influential factor is likely the significant percentage of accommodations in the 7e Arrondissement with inadequate level of energy performance. Given the older age of many buildings and the insufficient insulation, they often require considerable amounts of energy to achieve thermal comfort. In addition, the affluence of the neighborhood's inhabitants suggests a potential willingness to spend more on energy bills.

Information regarding the embodied carbon of the buildings is hard to retrieve since the vast majority are old, existing buildings that do not have accurate record of the materials and the construction process used. As seen in **Table 2**, A rough estimate can be provided based on a literature study that correlates Whole Life Carbon (WLC) emissions with building height and urban density.[80]

78 Urban Design Studio (2018) Borough of Islington's study report on Tall buildings. Borough of Islington. Retrieved from https://www.islington.gov.uk/~/media/sharepoint-lists/public-records/planningandbuildingcontrol/publicity/publicconsultation/20212022/20210718islingtontallbuildingsstudypart1.pdf
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Table 2. Case studies analysis findings about embodied carbon and operational carbon

Boroughs	Density (people/ km2)	Average number of storeys	Operational carbon (based on gas and electricity consumption data, tnCO2e/capita/year)	WLC emissions for 60 years (based on density and building height, tnCO2e/capita)
Islington	14,591	5-25 (middle-tall)	1.1	370
7e Arrondissement	11,953	3-8 (low)	1.9	190
Kingston Upon Thames	4,820	middle-low	1.4	340

Moving to aspects related to transportation demand, the traffic volume per person was found to be, as expected, significantly higher as the area is distanced from the center. Kingston upon Thames habitants experience four times more intense traffic, in other words they use vehicles four times more than people in Islington. The remarkably longer average distance between suburban regions like Kingston upon Thames and the city center where the economic activity, and the recreational and public facilities are gathered, as well as the sparsity of amenities like schools, as can be seen in **Table 1**, fortify the necessity of driving many kilometers per day by car to reach central London and benefit from the gathered amenities. The lack of attractive alternatives is also apparent, since there are limited public transportation options, like bus and metro lines and bike sharing stations (see **Table 3**) with considerably lower frequency and in farther proximity; factors that can be extremely deterrent especially in the hectic everyday life.

Finally, green spaces in terms of area and accessibility are significantly higher for city centre-distant boroughs with consequences on the air quality reflected in the comparison between Kingston upon Thames and Islington (see **Table 1**).

Table 3. Case studies analysis findings about transportation needs and available

Boroughs	Average time to downtown (mins)	Average walking time from a metro/train station (mins)	Number of bus lines (per km2)	Metro lines	Bike sharing stations (per km2)	Cars-only traffic volume (vehicle-kilometre, VKT)
Islington	22	7	1.1	9	2.4	276
7e Arrondissement	0	3.5	3.9	4	7.6	No data
Kingston Upon Thames	45	19	0.6	0	0	817

6. CONCLUSION

Tackling the complex issue of climate change will require breaking the silos and fostering a holistic vision, as well as a system thinking and dynamic collaborative approach.[81] Key decision makers must collect quality and robust data to take informed decisions while nurturing transparent and concerted relationships with citizens living in cities. City planners must concentrate on the following three elements of the built environment: **transportation**, **life cycle carbon emissions**, and **green infrastructures** as they have a high impact on social, environmental and economic aspects of living in urban ecosystems.

We found that when moving away from the centre (i.e., boroughs far away or badly connected to the city centre), public transportation services dissipate, further encouraging car use and deteriorating the quality of life. Indeed, transportation greatly affects carbon footprint of city residents, as well as their quality of life. It has been proved, for example, that using your bike to commute to work truly improves your productivity, therefore impacting the economy. As for life cycle carbon emmisions, denser areas tend to have lower overall carbon footprint due to the proximity – however it is not black and white as operational energy of buildings could make the carbon balance tip. As for the green infrastructure, the evidence is clearly reflecting our hypothesis on how the connection to nature, in a city, impacts positively well-being related indicators.

6.1 KEY LEARNING OUTCOMES

There is a growing need for transdisciplinary research and collaboration to address the issue of sustainability in our growingly complexified world. Indeed, a holistic approach is required regarding infrastructure planning and construction. Enhancing transdisciplinary training and education, coupled with a stronger emphasis on strategic circular and systems thinking, could serve as a critical launching point.

But should we even build at all?

80 percent of the buildings standing today will still be in use in 2050[82], while the demand for resource preservation and elimination of construction emissions implies a huge need – perhaps a substantial opportunity – to retrofit existing assets. There are non-energy benefits of retrofitting too, such as better thermal comfort for inhabitants, higher productivity, and better quality of life, preserving historic or culturally significant buildings, increasing property value, lowering carbon footprint, amongst others. Adding to this, it is estimated that close to one million homes in the UK are currently unoccupied, either being uninhabitable or merely serving as infrequent second homes. Properly refurbishing and repurposing these underutilised properties could significantly address the gap in the national property market.[83]

The most environmental building might just be the building we have already built. Why not think about harnessing and making improvements to these existing structures to increase their occupying capacity and make them more energy-efficient, comfortable, and sustainable? Some are even advocating for a necessary rethiking of our 'confort' conceptualisation. This is something decision makers and planners should not exclude from the urban densification planning discourse and how we will have to address the green just transition.

81 Net Zero Cities (2018) Net Zero Cities (n.d.) Why Climate Neutrality Requires Systemic Innovation. Citing Mazzucato, M. (2018) Net Zero Cities.
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No one-size-fits-all

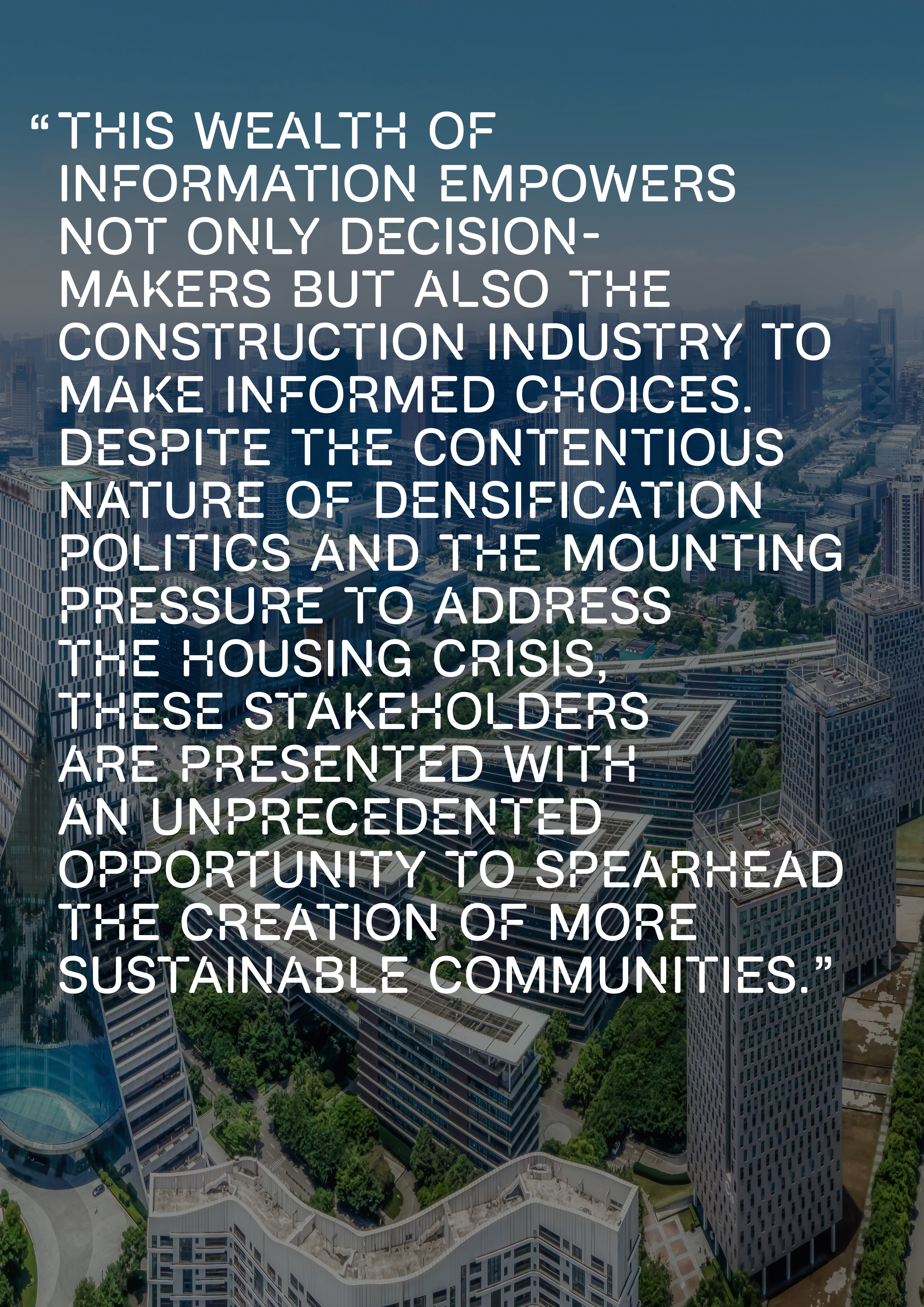
As land is a valuable and scarce resource, not all cities can adopt these soft density patterns. Some cities, such as London, need high-rise development to maximise the use of brown-field land use to avoid building on their green belt[84], whereas the actual ability of cities to modulate density is under question (see note below).

Some tall buildings now have the capacity to integrate cutting-edge energy efficiency technologies, to provide rooftop gardens or to adopt vertical greenery, while some are poorly designed – reinforcing isolation or the lack of green spaces. Conversely, certain low-rise developments, such as single-family detached homes, may contribute to a higher carbon footprint compared to taller structures, while also placing additional strain on infrastructure. In contrast, mid-rise buildings can often strike a more effective balance, offering environmental, economic, and social benefits.

Every city and every neighborhood are and will be different. Ultimately, there is no one-size-fits-all approach. Instead, planners, decision makers and developers must carefully consider the unique needs and challenges of each urban area and balance environmental contexts and housing demands. Soft densification also needs strong strategic planning frameworks to provide facilities and services whilst avoiding problems with overcrowding. They must couple mid-rise buildings, with transit-oriented developments, modern retrofitting policies, renewed zoning laws, highly sustainable building standards, and conscious and inclusive urban planning.

84 Livingstone, K. (2001) London needs some more clusters of tall buildings: 'High buildings should be assessed by what they add to the skyline, rather than what they take away'. The Independent. Retrieved from https://www.independent.co.uk/voices/commentators/ken-livingstone-london-needs-some-more-clusters-of-tall-buildings-9172567.html.

Note: In 1875, Octavia Hill, the founder of the National Trust, called for a 'green belt' around London to stop urban sprawl into the countryside. It wasn't until 1947 that her wish was granted. Presently, there are 15 green belts encircling England, encompassing over 16,000 km², which accounts for 12.6 percent of the nation's total land area. London's belt is the largest, spanning more than 5,000 km². The predominant land use, as of 2018, is agricultural, comprising 65.6 percent of the total area. The, very political, question of whether to build on this belt should be at the heart of a planning reform discussions. According to Centre for Cities, release the development green belts or agricultural land within 800 meters of any station with a service of 45 minutes or less to a large city, "if, but only if, that land has no marker of amenity or environmental value", excluding National Parks, Areas of Outstanding Natural Beauty, or public recreational areas.



"THIS WEALTH OF INFORMATION EMPOWERS NOT ONLY DECISION-MAKERS BUT ALSO THE CONSTRUCTION INDUSTRY TO MAKE INFORMED CHOICES. DESPITE THE CONTENTIOUS NATURE OF DENSIFICATION POLITICS AND THE MOUNTING PRESSURE TO ADDRESS THE HOUSING CRISIS, THESE STAKEHOLDERS ARE PRESENTED WITH AN UNPRECEDENTED OPPORTUNITY TO SPEARHEAD THE CREATION OF MORE SUSTAINABLE COMMUNITIES."

6.2 RECOMMENDATIONS

1. **Enhancing education and industry trainings and practices on holistic approaches to sustainability and systems thinking.**

   In engineering firms, at all levels, there is a need for appreciating the value in integrated and systems thinking and then providing training and career paths for staff, who may come from traditional or new backgrounds

2. **Fostering multi-sectorial collaboration.**

3. **Adopting soft density approaches (high-density, mid-rise and mixed used "agglomeration"[85]), tailored for the peculiarities of every area. Adding to this, this means prioritising smart growth principles, green building practices and integrating sustainable grey, blue and green infrastructure.**

   At the local level, there is a need to proactively identify suitable sites for higher density mixed-use residential intensification capitalising on the availability of services within walking and cycling distance, and current and future public transport provision.

4. **Retrofitting the existing building stock – the most sustainable urban development strategy, with appropriate energy performance improvement, maximum resource efficiency can be attained. Circular economy standards should be**

Future Avenues of Research

Densification planning and developments, both 'hard' and soft, need careful monitoring and regulation to prevent city overcrowding and unsustainable environments. While there is a noticeable discrepancy in locally comparable data across metropolis and cities on the globe, and an enormous gap between Global South and Global North literature – engineers and decision makers have now at their disposal robust data, studies and public consultation reports on the livability and sustainability of the built environment and urban designs.

This wealth of information empowers not only decision-makers but also the construction industry to make informed choices. Despite the contentious nature of densification politics and the mounting pressure to address the housing crisis, these stakeholders are presented with an unprecedented opportunity to spearhead the creation of more sustainable communities.

85 For example, in London (UK), the London Plan's (2016) recommended maximum density threshold for the highest Public Transport Access Level (PTAL) setting 6 and the Central Character setting is 405 units per hectare. In the 2020 London Plan, there is however no maximum density level, but instead promotes design-led where the optimal density for allocated sites is determined by Boroughs. Considering this there is no need from purely a residential density point of view to promote tall buildings, as increased densities can equally be achieved with compact medium-rise development forms such as **urban perimeter blocks**. For example, in some residential areas, courtyard type layouts ("courtyard housing") that consider micro-climates, daylight and beneficial solar gains, and private and semi-private green space configurations, might be prioritised.

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Born in Turkey, Lara is an Industrial Engineer with masters in Business Analytics with an interest in sustainability but especially that of in the built environment. Her engineering and data science background is bringing a new perspective to the sustainability area and she is aiming to use the power of data to better understand the issues in the built environment. She is interested in using the emerging new technologies to increase the sustainability aspect of the built environment.

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