UNIVERSITY OF ICELAND

Aalto University

Doctoral Thesis
in Environmental Studies & Architecture, Landscape and Urbanism

Zoning for Zero

Climate impacts of zoning plans in a Nordic context

Teemu Jama

May 2026

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING IN UNIVERSITY OF ICELAND
SCHOOL OF ART, DESIGN AND ARCHITECTURE IN AALTO UNIVERSITY

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Thesis Dissertation in partial fulfilment of a
Philosophiae Doctor degree
in Environmental Studies and a *Doctor of Science* degree in Architecture, Landscape and Urbanism.

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Bibliographic information:
Teemu Jama, 2026, *Zoning for Zero: Climate impacts of zoning plans in a Nordic context*, Doctoral dissertation, Faculty of Civil and Environmental Engineering, University of Iceland and School of Art, Design and Architecture, Aalto University.

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ISBN 978-9935-578-05-1 (PDF, University of Iceland)
ISBN 978-952-64-3184-0 (PDF, Aalto University)

Abstract

This thesis examines the climate impacts of urban planning, with a focus on its primary institutional outcome: zoning plans. Methodologically, it contributes by analysing planning paradigms, typically addressed qualitatively in normative terms, through quantitative methods based on high-resolution spatial data of the built environment classified by their zoning plan denotations. Using this mixed-method approach grounded in Critical Realism, the thesis provides *quantitative evidence* on how land-use zoning influences the carbon footprint of urban development, with a *qualitative analysis* of the mechanisms behind this evidence.

The quantitative results from the Nordic case cities challenge prevailing assumptions from two directions. On the one hand, high-density, efficiency-oriented zoning seems to fail to enable argued low-carbon lifestyles, instead reinforcing high-carbon behaviours through consumerism and increased travel. On the other hand, lower-density zoning, widely deemed unsustainable, tends to dominate also in cities in locations where residents have lower carbon intensities and overall emissions, even when income and household types are controlled. The findings reveal zoning's *causal power* to shape global emissions from the bottom up, although it is currently applied counterproductively.

The thesis demonstrates and argues that using zoning plans to manage climate impacts, rather than building rights with per capita–based efficiency metrics, is not only a feasible and historically defensible reconception of zoning but also essential for urban planning to retain its public mandate as a libertarian paternalistic policy tool for climate-friendly development.

Útdráttur

Í þessari ritgerð eru loftslagsáhrif borgarskipulags rannsökuð, með áherslu á helstu stofnanalegu afurð þess: skipulagsáætlanir . Aðferðafræðilegt framlag ritgerðarinnar felst í því að greina skipulagsviðmið, sem venjulega er fjallað um á eigindlegan hátt út frá gildismati, með megindlegum aðferðum sem byggja á nákvæmum staðbundnum gögnum um hið byggða umhverfi, flokkuðum eftir skipulagsskilgreiningum þeirra. Með því að beita blandaðri aðferðafræði sem byggir á gagnrýninni raunhyggju, leggur ritgerðin fram megindlegar vísbendingar um hvernig landnotkunarskipulag hefur áhrif á kolefnisspor borgarþróunar, ásamt eigindlegri greiningu á þeim ferlum sem liggja að baki þessum vísbendingum.

Megindlegar niðurstöður úr norrænum tilfellarannsóknum vega að ríkjandi hugmyndum úr tveimur áttum. Annars vegar virðist þétt, skilvirknismiðað skipulag ekki stuðla að lágkolefnislífstíl eins og haldið hefur verið fram; þess í stað ýtir það undir kolefnisfreka hegðun með aukinni neyslu og auknum ferðalögum. Hins vegar er dreifðara skipulag, sem almennt er talið ósjálfbært, ríkjandi á svæðum þar sem íbúar hafa lægri kolefnisspor og heildarlosun, jafnvel þegar tekið hefur verið tillit til tekna og heimilishalds. Niðurstöðurnar sýna fram á orsakamátt skipulags við að móta losun á heimsvísu neðan frá og upp, þótt því sé nú beitt á gagnstæðan hátt.

Í ritgerðinni er sýnt fram á og færð rök fyrir því að notkun skipulagsáætlana til að stýra loftslagsáhrifum — í stað þess að nota byggingarrétt byggðan á skilvirknimælikvörðum á hvern íbúa — sé ekki aðeins raunhæf og sögulega verjanleg endurskilgreining á skipulagi, heldur einnig nauðsynleg til þess að skipulagsmál haldi opinberu umboði sínu sem frjálslynt forsjárhyggjutæki í þágu sjálfbærrar þróunar.

Tiivistelmä

Tämä väitöskirja tarkastelee kaupunkisuunnittelun ilmastovaikutuksia keskittyen sen lainvoimaiseen institutionaaliseen lopputulokseen, eli kaavakarttaan. Metodologisesti tutkimus analysoi kaavojen ohjaussisältöä – jota tyypillisesti käsitellään kvalitatiivisesti – kvantitatiivisten menetelmien avulla. Menetelmä nojaa Kriittiseen Realismiin (Critical Realism) yhdistäen empiiriset havainnot asukkaiden elitapojen päästöistä heidän asuinympäristönsä maankäyttötyyppeihin luokiteltuna kaavamerkintöjen tapaan. Näin tehden tutkimus tarjoaa empiiristä näyttöä siitä, miten maankäytön kaavoitus (zoning) vaikuttaa kaupunkikehityksen ja elintapojen hiilijalanjälkeen.

Tutkimustulokset Pohjoismaisista pääkaupungeista haastavat vallitsevat kestävyysoletukset kahdesta suunnasta. Toisaalta tiivistymistä hakeva tehokkuuskeskeinen kaavoitus ei näytä mahdollistavan väitettyä vähähiilistä kaupungin toiminnallisuutta, vaan sen sijaan vahvistaa hiili-intensiivisiä elintapoja kuluttamisen ja lisääntyneen matkustamisen kautta. Toisaalta väljä maankäyttö, jota on usein pidetty epäkestävänä, näyttää hallitsevan sijainneissa, joissa asukkaiden hiili-intensiteetti ja kokonaispäästöt ovat kaupungissakin alhaisemmat tulotasoihin ja kotitaloustyyppeihin katsomatta. Tulokset paljastavat kaavoituksen kausaalisen voiman muokata globaaleja päästöjä alhaalta ylöspäin.

Väitöskirja väittää, että kaavasuunnitelmien käyttö ilmastovaikutusten hallintaan tehokkuutta lisäävien korkeiden rakennusoikeuksien sijaan on tehokas, tärkeä ja perusteltu kaavoituksen uudelleenroolitus. Se on myös välttämätön, jotta kaupunkisuunnittelu voi säilyttää mandaatin julkisin varoin ylläpidettävänä yhteiskunnan etua ajavana interventiovälineenä.

Dedication

I dedicate this thesis to future generations living long, healthy lives in harmony with our only planet, in cities, the countryside or in between.

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List of Publications

This doctoral dissertation consists of a summary and of the following publications, which are referred to in the text as Articles or Papers by their numerals (i.e. Article A1. or Paper A1.). Publications are listed as Analysis articles (A1, A2, A3) and Background articles (B1, B2).

A1: Jama, Teemu; Tenkanen, Henrikki; Joutsiniemi, Anssi; Lönnqvist, Henrik. 2024. *Compact city and urban planning: Correlation between density and local amenities.* In: Environment and Planning B: Urban Analytics and City Science. DOI: https://doi.org/10.1177/23998083241250264

A2: Jama, Teemu; Heinonen, Jukka; Tenkanen, Henrikki. 2025. *Impact of Land-use Planning on Lifestyle Carbon Footprints.* In: Environments, 13(3), 173. DOI: https://doi.org/10.3390/environments13030173

A3: Jama, Teemu; Heinonen, Jukka. 2025. *Zoning for Zero: Critical realist analysis of urban plan-making for carbon-neutral cities.* In: Carbon Footprints, 2025, 5,21. DOI: https://doi.org/10.20517/cf.2025.35

B1: Page, Mathew; Joutsiniemi, Anssi; Vaattovaara, Mari; **Jama, Teemu**; Rönnberg, Oskar 2024. *Density as an indicator of sustainable urban development: insights from Helsinki?* In: European Planning Studies, 32:10, 2182-2202. DOI: 10.1080/09654313.2024.2370314

B2: Wang, Tiangi; **Jama, Teemu**; Tenkanen, Henrikki. 2025. *Assessing the livability within the 15-minute city concept based on mobile phone data.* Computers, Environment and Urban Systems (accepted with revisions).

Contribution of the author.

Article A1: Substantial contributions to the conception and research design of the study, data acquisition, visualisation, and writing work.

Article A2: Substantial contributions to the conception and research design of the study, data acquisition, visualisation, and writing work.

Article A3: Substantial contributions to the conception and research design of the study, data acquisition, visualisation, and writing work.

Articles B1 and B2: Contribution to feature engineering and conclusion writing work from the perspective of urban planning practice.

List of Used Acronyms

• CR: Critical Realism,
• EDA: Exploratory Data Analysis,
• EIA (plural EIAs): Environmental Impact Assessment,
• EU: European Union,
• GFA: Gross Floor Area,
• GHG: Greenhouse Gas,
• GWP: Global Warming Potential,
• GIS: Geographic Information System,
• HSY: Helsingin seudun ympäristöpalvelut (Helsinki Region Environmental Services),
• SYKE: Suomen Ympäristökeskus (Finnish Environment Institute),
• YKR: Yhdyskuntarakenteen seurannan ruutuaineisto (Grid dataset for Urban Structure),
• OPC: One Person Companies,
• LCA (plural LCAs): Life Cycle Assessment,
• PCF: Personal Carbon Footprint,
• MAUP: Modifiable Areal Unit Problem,
• UGCoP: Uncertain Geographic Context Problem,
• UPD: Urban Planning Data

Acknowledgements

This dissertation was created under a cotutelle agreement between the University of Iceland and Aalto University in Finland. At the University of Iceland, such doctoral research is overseen by a "scientific committee" composed of professors from related fields. This arrangement gave me the opportunity to assemble the most competent support team for my research.

I am deeply grateful to the leading expert on planetary sustainability, Professor *Elisa Lähde* at Aalto University's Department of Architecture, and to the geo-analytics specialist, Professor *Henrikki Tenkanen* from the Department of Built Environment in Aalto, and especially to the top climate-research scholar who served as my lead supervisor, Professor *Jukka Heinonen* at the University of Iceland. Through these professors, I have also become acquainted with three research groups from different disciplines, each home to emerging high-profile scholars whose work the world will soon hear about. I would also like to thank Professor *Anssi Joutsiniemi* from the Department of Urban Planning at the University of Oulu and Professor *Mari Vaattovaara* from the Department of Geosciences and Geography at the University of Helsinki, who initially drew me to this doctoral study. This dream team has provided me with both funding opportunities through involvement in their projects and world-class expertise that my own academic path required for this work. I would also like to extend my special thanks to The University of Iceland Science Park (Vísindagarðar), whose funding was critical for me to bring this multidisciplinary journey to completion.

Finally, I express my sincere gratitude to my beloved family – Kaisa, Saima, and Isla – who allowed me to occasionally participate in family efforts from the comfort of our couch, reading articles on an iPad. Without the encouragement, guidance, and resources provided by all of these individuals, many of the claims put forward in this dissertation would have remained in doubt.

Teemu Jama

1 Introduction

Urban areas are increasingly recognised for their profound impact on climate change. For example, many global cities engage in low-carbon initiatives and promote climate-friendly strategies, while academic research enhances understanding and develops novel methods such as Environmental Impact Assessments (EIAs) and Life Cycle Assessments (LCAs). However, these assessments and strategies have had only a limited practical impact on planning (e.g., Corredor-Ochoa et al., 2020; Creutzig et al., 2025; Hautamäki et al., 2024; Jay et al., 2007; Lähde et al., 2025; LeGates and Stout, 2020; Säynäjoki et al., 2014). The lack of impact has also been recognised at the EU level. The EU has developed Global Warming Potential (GWP) accounting regulation toward more data-driven measurement and reporting while identifying a dual problem: on one hand, assessment calculations are not sufficiently integrated into planning, and on the other, they place an excessive burden on operators (Omnibus I - COM(2025)80, 2025). In addition, the EIAs seldom account for the indirect emissions *enabled* by the action or product under assessment after implementation. For example, in the EU Green House Gas (GHG) accounting protocol, three "scopes" that categorise direct and indirect impacts, the indirect term used in the scopes 2 and 3 refers to the internal life-cycle perspective of the materials and energy needed to implement the "product" itself (e.g., a building) (Präger et al., 2025). The external impacts and emissions generated by the activity that the product facilitates are left outside (such as consumer urban liveability in the case of urban planning). Hence, some scholars have proposed expanding the existing three-step scoping to "scope 4", which aims to account for external emissions avoided because of the product (e.g., De Giovanni, 2025: 4; Young-Ferris et al., 2025). Assessing urban planning, especially zoning plans, as a product can be argued to fall within the scope 4, because they facilitate selected urban development and lifestyle in cities. However, in planning practice, the sustainability of urban plans is predominantly measured using per-capita metrics for infrastructure supply (e.g., energy footprint per capita) and operations (e.g., transit accessibility per resident) (Berghauser Pont et al., 2021). This creates a sustainability paradox within the scope 4: to achieve favourable efficiency metrics, the system relies on intensive usage and infrastructure densification, which may, counterintuitively, increase absolute emissions even as per-capita emissions decline, resulting in real-estate projects with high accounts in scopes 1, 2 and 3, also having an external impact on residents' lifestyle emissions.

This dilemma lies specifically at the heart of the so-called *compact city* ideal, which is particularly prevalent in Nordic urban planning (Haarstad et al., 2021; Hall, 2003). The core sustainability belief underpinning the compact city model appears to rest on two hypotheses: first, that residents will live locally using sustainable transit modes when amenities are nearby (e.g., the 15-minute city concept); and second, that high-density urban plans will create the conditions for these amenities to emerge locally. These hypotheses link lifestyle ideals to per capita infrastructure optimisation goals in planning practice. However, empirical research from a *user perspective* questions the arguments. Surveys have indicated that leisure travel increases with higher residential density (Czepkiewicz et al., 2018; Raudsepp et al., 2024), and residents living in the most diverse locations tend to travel more on a regional scale, making the 15-minute city a reality only for those with poor mobility

capabilities (Vale and Lopes, 2023; Zhang et al., 2025). Similarly, it is questionable whether local amenity development – a prerequisite for the mundane life of the local – will follow high-density development, as services tend to serve regional clientele (Culley, 2020).
Furthermore, from an emissions perspective, if diverse amenities emerge in particular locations – for example, due to high regional connectivity serving non-local residents – the mitigation effect of locals' mobility modes may be overshadowed by consumerism stemming from the more frequent use of those same amenities (Ottelin, Ala-Mantila, et al., 2019). Hence, a clear disconnection between the ambitious goals outlined in sustainability strategies and the routine practices of urban planning has been widely noted (e.g., Berghauser Pont et al., 2021; Ferreira and Batey, 2011; Hautamäki et al., 2024). What if urban planning, as a form of public intervention, while aiming to guide development according to strategies, leverages paradigms that primarily facilitate highly consumer-oriented lifestyles (e.g., 'urban buzz'), results in ever-higher global emissions? This indirect contribution would add to the well-known direct emissions from carbon-intensive construction methods needed in high-density environments (e.g., replacing soil with concrete, steel, and asphalt).

Given that indirect lifestyle-related impacts are rarely studied from a zoning perspective, even though planning strongly advocates pursuing a sustainable city life, a critical research gap has been identified: *The need for more nuanced studies to understand how zoning plans affect lifestyle carbon footprints, isolating their effects from non-zoning-related factors such as affluence.*

This thesis, therefore, explores the impact of contemporary *land-use features*, as designated in zoning maps, on the carbon footprints of the urban development they facilitate. This perspective differs from the established scopes of Life Cycle Assessments (LCA), which assess the optimisation level of specific implementation projects. Zoning (urban planning and design), on the other hand, *mandates the scale* at which LCA methods fine-tune. The climate crisis is about the scale, not the optimisation details.

The exploration is conducted bottom-up, from the perspective of residents' lifestyle carbon footprints associated with "zoned development". Focusing on affluent Nordic countries where footprints are high despite strong environmental policies, the research will particularly examine Personal Carbon Footprints (PCF, see detailed explanation in Article A2) related to services and travel, both of which are common planning themes. The present condition study is extended towards the future, as planning does, by analysing whether the zoning plan could be directly aligned with climate mitigation goals. Through this *trans-epistemological* bridge, moving from empirical quantitative research findings to qualitative insights into the social mechanisms underlying the plans, the thesis seeks to contribute to a future-oriented understanding necessary to address ongoing transgressions of planetary boundaries.

The study unfolds in five stages. First, the following sections (1.1–1.4) present the theoretical background, research context, scope, and research questions. The aim of Chapter 1 is to position the research in-between the traditional, discipline-based scholarly continuum and provide the rationale for this. Chapter 2 operationalises the scope by explaining the research design and methodological rationale. Chapter 3 summarises the evidence gathered from the articles. The compilation and summaries of the articles are intentionally concise, as all works (excluding B1) are open access and available for the public to explore in more detail. In Chapter 4, the results are discussed for evaluation and synthesis, driving the final conclusions in Chapter 5.

1.1 Zoning plans as urban planning

In the Nordics, where urban planning is often framed as a rational, technocratic tool for managing growth, densification as a general policy can be understood as part of a broader regime of widely discussed urbanisation. The scope of work undertaken by planning institutions encompasses a wide range of activities beyond the preparation of zoning documents. Despite being less visible to the public, these activities (e.g., public-private development partnerships, financial agreements between state and cities for housing plan production, interim activities leases, and legal autonomy of traffic planning operating in-between land-use zoning areas) may have a transformative impact on the built environment, steering urban development in ways that are more consequential what is captured in official zoning documents (Vaattovaara et al., 2021; Rantanen and Rajaniemi, 2020; Lampinen, 2015). However, in many cases, such activities eventually necessitate formal zoning amendments, or zoning plan revisions may even be their primary objective, as with housing production agreements that facilitate faster growth. The growth-oriented policies, combined with implementation-oriented contemporary planning (Flyvbjerg, 1998; Friedmann, 2008) within a municipal structure in which neighbouring cities compete, make the pursuit of numerical efficiency gains advocated by engineers understandable. From this reality, this thesis frames zoning plan-making not purely as a technical blueprint but as a techno-practice that is a politically coloured, selectively data-based, institutionally driven business field for civil servants, consultants, and developers. From an academic planning research perspective, this practice-oriented view is much aligned with Foucault's concept of *dispositif* (Pløger, 2008)[1]. The“zoning dispositif” here is the shared set of norms, technical tools, representations, and arguments used to produce zoning maps as the end product of planning.

This framing, treating zoning plans as a representation of urban planning thinking, is, however, challenged by noted implementation-oriented practices that fine-tune plans to developers' needs. In addition, the zoning paradigm itself has been criticised for failing to meet more nuanced planning goals due to its reductiveness (e.g., Lehnerer, 2009; Rantanen and Rajaniemi, 2020). However, the focus of this study is not the implementation details nor the institutional nuances of practice, but the very reductiveness of zoning ordinances, which constitute the commensurate layer within zoning traditions across countries (see: ARL Country profiles, 2021). Through these common ordinances, the zoning maps fuse current political trends with institutional ideals into a legal blueprint that enables specific patterns of development and habitation while excluding others. In this way, zoning plans lock in established thinking and exert strong *causal power* over urban development (Næss, 2015).

In this context, both terms, 'plan-making' and 'zoning', refer to the same action. This view excludes, for example, urban design illustration documents, which are often created for goal-defining or marketing purposes within the planning process. According to this view, the impact of urban planning depends on the composition and designations in the legal zoning plan, not on the accompanying illustrations. Accordingly, this scope focuses on the categorisation called *land-use planning*, a term commonly used in practice to distinguish it

[1] *Wikipedia lists several translations for the Foucalt´s term dispositif: "device", "machinery", "apparatus", "construction", "formation" and "deployment". (Wikipedia 6.12.2025). These all illustrate well also the zoning plan as an instrument which deploys established power be it institutional, professional or political down to the blueprint implementation of a built environment.*

from transportation planning. However, scoping out traffic engineering as a discipline is not unproblematic from the perspective of the topic. Traffic arrangements are an integral and spatially significant part of the urban environment, and their planning relies particularly heavily on density-driven theories for proximity and modelled modes of transport (Ferreira and Batey, 2011; Kesarovski and Hernández-Palacio, 2023; Lampinen, 2015). Furthermore, the impacts of transport infrastructure on climate change are particularly substantial, both directly and indirectly (Erickson and Tempest, 2011). For these reasons, addressing traffic planning theories and goals in this manner is too broad a task to fit within the scope of a single dissertation. However, transportation planning is integrated within the zoning perspective, and is analysed in terms of its land-use-related goals (i.e., Article A1).

1.2 Nordic context in urban planning

The thesis title uses the term 'in a Nordic context', but that part could also be written '*from* a Nordic context', because although the data and cases are Nordic-based, the conclusions extend globally. Nordic context is sound for the research scope, since the urban planning institutional frameworks shared by the Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) all including ambitious climate policies and a top-down zoning regulation tradition (Haarstad et al., 2021; Hall, 1991), the impact of zoning can be analyzed more reliably than in countries with more laissez-faire approaches. However, the concept of Nordics is not unambiguous. Haarstad et al. (2021) point out that forcing these countries under the same category is often politically constructed. This view is also elaborated by Hall as early as the 1990s (Hall, 1991). However, in the context of urban planning, as a public governing instrument, the concept of Nordics is more justified. Urban planning as a profession and the legal planning system, as its national institutional condition, created within the democratic welfare state project in the 20th century, bring Nordic countries closer together. This is also the case in Iceland, where modernist zoning instruments were introduced after WWII, even though polluting factories and coal-fired power plants, which needed to be zoned away from housing, were rare in this geothermal country (Valsson, 2003). By focusing on the much-contested concept of urban planning through its legal instrument, zoning plans for ‘physical planning’ (as Hall defines it), establish a common legitimate foundation for discussing the Nordic context in urban planning, including Iceland.

The development of planning systems and corresponding building laws occurred during roughly the same period throughout the 20th century, with all countries essentially following and adapting from one another (Hall, 1991). In Iceland, the development of general administration differed more from that of the others due to its unique governmental history. Nevertheless, the rapid adoption of comprehensive planning trends and modernist ideals has kept the modern planning system somewhat similar to its Nordic counterparts (Valsson, 2003). This similarity remains evident, for example, in the Reykjavík Master Plan 2016, which included all the ingredients, arguments, and goals found in other Nordic capital master plans in contemporary times. Indeed, Nordic planning has been characterised by a strong political consensus around sustainability goals at an abstract level (Nordregio et al., 2018). However, these goals are not fulfilled in planning practice (Hautamäki et al., 2024; Tilsted et al., 2021).

Probably because of these shared ideals, the planning administrations have also shared similar challenges, such as the lack of institutional clarity of different agencies, the

competitive setting of municipalities, and deregulation of zoning for financialization with downscaling of housing policies (Hall, 1991; Jay et al., 2007; Valsson, 2003). Given that the relocation of industrial production to other parts of the world leaves Nordic cities today without direct externalities to manage through zoning, one might ask what zoning is for today. These notions in the Nordic context emphasise the importance of increasing understanding of the *indirect* climate impacts and capabilities of the zoning instrument itself.

1.3 Theoretical framing

Epistemologically contemporary Nordic urban planning practice can be characterised by a divergence between the quantitative rigour of transport engineering and the creative spatial focus of architecturally flavoured land-use design. While these traditions have provided valuable insights into functionality, their differing epistemologies present challenges for fully addressing the systemic nature of climate change. Theories regarding density and compact urban form, in particular, appear to result from an *'epistemic amalgam'* – a historical convergence where the positivist tradition of transport modelling meets the normative idealism of architectural design. Drawing on a practice-based hermeneutical perspective, I use the following division to substantiate this argument:

The Quantitative Tradition: Transportation planning models often follow a Humean logic, viewing causality as "constant conjunctions" (e.g., measured sustainable travel modes in densely built regional city centres used inversely to forecast similar modes based on high-density plans for edge city locations). This approach risks treating complex impacts as "externalities" outside its modelled optimisation focus (see Article A1 and e.g., Joutsiniemi, 2010; Lampinen, 2015; Ylä-Anttila, 2010).

The Normative Tradition: Conversely, urban design relies heavily on hermeneutic intuition and artistic idealism, prioritising established normative visions. This approach risks an idealist bias, focusing on what should be, rather than engaging with the intransitive reality of biophysical and socio-economic constraints (see Article A3 and e.g., Hillier, 2015; Samuel, 2018).

This convergence is also evident in recurring urban ideals, from Sir Ebenezer Howard's Garden City and Clarence Perry's Neighbourhood Unit to the Finnish "Metsälähiö" (Forest suburb) and the contemporary 15-Minute City concept (see Articles A3 and B1). These concepts, as a design thinking approach for zoning documents, successfully merge the engineer's desire for modelled per-capita efficiency with the designer's appeal to the "human scale" in the densely built historical city centres.

Critical Realism as a bridge

Utilising Roy Bhaskar's Critical Realism (CR) provides a practical philosophical bridge to overcome the 'epistemic amalgam' described. This is achieved specifically through its "non-Humean" ontology and the concept of the "laminated system", which divides reality into three levels: *Real, Actual and Empirical* to seek a more nuanced understanding of evidenced development (Bhaskar, 2010). CR perspective suggests that if planners focus only on the physical shape or measure of a city without analysing the underlying social and economic forces it relies on or drives, they create "chaotic conceptions" – the term used by Sayer for

an abstraction that groups outcomes without identifying the actual mechanisms they are part of (Sayer, 2010). In planning, the term can be used to describe certain ideals that are grouped together – such as urban liveability, the eco-friendliness of urban travel modes, and per-capita efficiency measures – without considering the causal mechanisms needed to produce those results, nor their external impacts. In this sense, the philosophy of CR is closely related to the *system theory*. The shared goal of system theory approaches has been to focus on the wholeness (system) rather than to reduce thinking to the boundaries of a selected element within the system (Joutsiniemi, 2010). According to Joutsiniemi, the roots of system theory are strongly linked to the concept of complexity, the (mathematical) theory of communication and the role of modelling in planning practice (Joutsiniemi, 2010). Similarly, systems theory resonates with contemporary landscape architecture, which aims to manage complex socio-ecological systems holistically within the planning process (e.g., Elmqvist, 2013; Lähde, 2020).

A land-use zoning map is a highly simplified model of the desired future, in which environmental complexity is reduced to a set of selected control variables, such as building rights and land-use types within the zone. The map-as-model is a communication tool for managing the complexity of urban development. As Joutsiniemi has pointed out, successfully managing complexity by controlling selected elements requires understanding the role of those elements within the larger system (Joutsiniemi, 2010). The excellence of CR is that its system-theory thinking suggests bridging not only isolated professions at the horizontal level (e.g., traffic engineers and architects as planners) but also actors in the vertical world (e.g., politics and institutional funders operating behind the needs that planners control and implement). CR shifts the focus from empirical impacts of the zoning designations (i.e. measurable land-use figures and calculated correlation in the Articles A1 and A2; the Empirical level) to the practices which produce them (Zoning and urban design thinking; the Actual level) and, furthemore, towards the beliefs and theories behind these pracitices such as the normative ideal of "compact city" or real-estate evaluation parameters for profitable investment and funding; the Real level (see Article 3).

De-mystifying 'theory' for practice

"Although many fear the term 'theory' itself, the basic meaning of this word simply means the gathering of knowledge and experiences in order to be better able to tackle the things humans occupy themselves with in daily life and work."

- Trausti Valsson, the first Professor of Planning at the University of Iceland

This quote by Trausti Valsson illustrates the practical perspective I have sought to maintain when applying Bhaskar´s Critical Realist philosophy. It is necessary to elaborate on the findings through Valssonian theoretical lenses, as theories *in* design thinking have not been central to planning theory research in academia (LeGates and Stout, 2020) or to the scope of practice hermeneutics. Focus group research in Finland as well as in Iceland has found that planners often feel that they have no means to advance sustainability issues when drafting the plans, even though they must handle numerous environmental impact assessments during zoning processes (Jay et al., 2007; Lähde et al., 2025; Säynäjoki et al., 2014). These notions call for paying attention to planning practices at the general level, i.e., at the *theoretical* level – focusing not on national institution-based practicalities but on shared commonalities. Zoning designations remain the practical core of these commonalities, which are anchored in theories of their sustainability impacts.

1.4 Research questions

As described above, the Nordic zoning tradition is widely justified by generative sustainability goals, yet practice still lacks a robust, systemic understanding of how zoning logic actually shapes indirect climate impacts. Within the theoretical frame set above, this thesis aims to contribute precisely to that *theory/practice vs their impacts –gap*. This focus deliberately positions the research at the intersection of, yet distinct from, multiple established academic disciplines, which are thoroughly referenced in the introductory sections of the constituent articles. This unique positioning ensures the research avoids being narrowly constrained within the isolated research traditions associated with this perspective, mainly with architecture and urban planning from the practice side, and urban studies conducted in fields such as urban economy, ecology and geography from the academia side. This approach allows the work to engage with the extremely complex themes of climate impacts and urban development in a comprehensible, practice-oriented manner while retaining scientific rigour in its methods.

The gap is approached by seeking the answers to the following research questions (RQs):

RQ1. To what extent does Nordic zoning meet its goals for local amenities and the low-carbon lifestyles it promises?
This general-level question addresses the paradox identified in the introduction. It aims to bridge the recognised gap between the means used in zoning and their actual impacts.

RQ2. How do specific land-use zoning designations correlate with residents' lifestyle carbon footprints when isolated from socio-economic factors?
This question addresses the critical need for more nuanced studies to understand how “zoned zones” relate to lifestyle carbon footprints at the local neighbourhood level, where contemporary implementation-oriented planning operates.

RQ3. Can the legal instrument of zoning be reconceptualised to shift its role towards systemic climate mitigation?
This question addresses the future-oriented aspect of zoning. It moves beyond the data-based assessments of the present toward the potential of the "zoning dispositif" in future.

2 Research design

The future, as a context (i.e., planners' context) for the analysis, operating on empirical findings from the present, called for a rigorous but trans-epistemological research design. Both the overall research design and the methods used in the analysis articles were shaped by the experiences and observations gained during the background articles. In this sense, both the research design and the technical innovations in geospatial analytics are also part of the scientific contributions, even though the primary thematic findings emerged from the analysis articles. Without the work, observations, and ideas for methodological targeting carried out in the background articles, the research design would not have come to fruition.

The general aim of the research design is to bridge *the empirical and the possible*, thereby moving beyond recognised challenges towards future possibilities, in keeping with the traditional role of urban planning (cities are not planned towards the past). To achieve this transition, the research employs a Critical Realist (CR) framework of reality domains (see 1.3). This approach allows the thesis to move beyond merely describing statistical correlations in the present data to identifying the hypothesis of "zoning dispositif" patterns that possess the causal power to shape climate-friendly future outcomes.

2.1 Replicated mixed-methods

The first phase of the analysis part (Articles A1 and A2) operates within the *Empirical domain*. Here, quantitative methods are employed to identify correlations between key zoning variables (density and land-use type) and observable phenomena (amenities, carbon footprints). Following a Critical Realist philosophy, these statistical associations are not treated as sufficient explanations in themselves. Instead, they are viewed as the observable traces (events) of deeper structures in discussions, moving research towards the *Actual domain*. This approach builds on a common mixed-methods rationale that aims to integrate diverse perspectives on the same phenomenon (Eisenhardt, 1989). In a theory-wise manner, joining statistical analysis with the qualitative insights on what the numbers mean for planning practice, moves from *variance theory* (statistical methods), used to establish empirical regularities, to *process theory*, aiming to identify not just regularities but causal mechanisms from the same numbers (Maxwell, 2010). In a case-wise manner, Articles A1 and A2 also follow a *replication logic* (Eisenhardt, 1989): A1, using the Helsinki region as case data, establishes the initial empirical base for the “Actual” level hypothesis, which is then tested for robustness through multiple-case replication in Article A2 by analysing the phenomena in a complementary manner across all Nordic capitals. Given the absence of clear initial hypotheses (e.g., regarding the impactful land-use types within particular carbon-footprint domains), the patterns are to be discovered and validated through an iterative analytical process across replications. To ensure methodological consistency across iterations, the design employs Wallace's (1971) Wheel of Science, incorporating data science perspectives from Kar et al. (2023). The wheel, as a repeatable “rolling” framework, defines a cyclical Exploratory Data Analysis (EDA) process within the research in Articles A1 and

A2, and also encapsulates the overall cross-epistemology nature of the thesis's design for future research needs (Figure 2.1.1).

In the second phase, Article A3 moves the methodological dialogue to the *Real domain.* This is done by applying Flyvbjerg's logic of the *'thought experiment'* to a real-world comparative case study to elaborate on the hidden possibilities of the zoning tool. It examines whether the same legal instrument, if recalibrated from implementation efficiency to climate compliance, can redirect its causal power to generate climate-friendly Empirical realities.

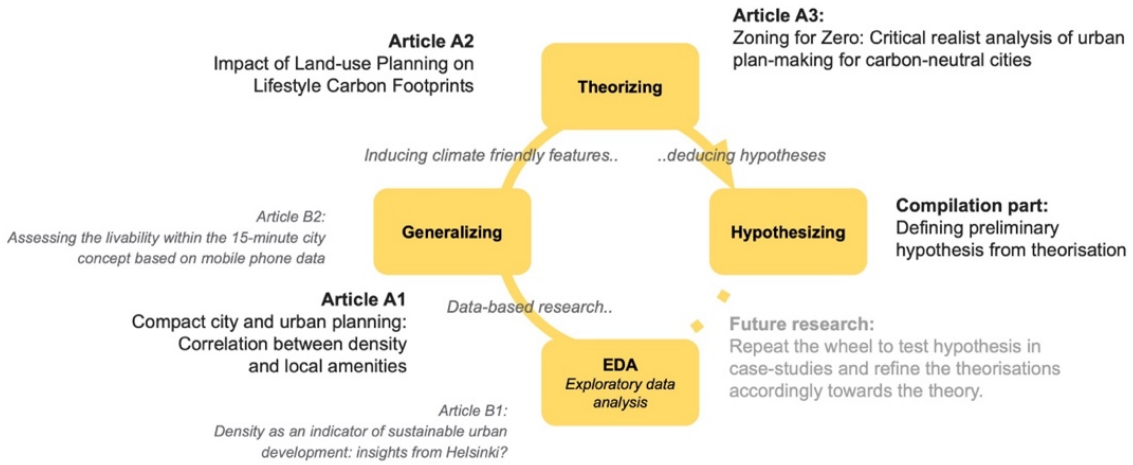

Figure 2.1.1 The Wheel of Science captures the research design with corresponding articles.

Tables 2.1.1 and 2.1.2 summarise the specific methods, purposes, data sources, and research questions of each paper.

Table 2.1.1 The purpose and the role of the analysis articles A1, A2 and A3.

	Publication A1	Publication A2	Publication A3
TITLE	*Compact city and urban planning: Correlation between density and local amenities*	*Impact of Land-use Planning on Lifestyle Carbon Footprints.*	*Zoning for Zero: Critical realist analysis of urban plan-making for carbon-neutral cities*
RESEARCH QUESTION	How urban density, as measured by GFA volume, correlates with the growth of urban amenities and liveability.	What are the correlations between the locally zoned land-use types and the personal footprints of residents?	Would it be realistic to use zoning to drive themes that are now assessed in EIA documents?

METHODS	Pearson correlation between the studied features in different geographical scales.	Spearman and Pearson correlation between the studied features in different geographical scales.	Analysis of the procedural impacts of climate-oriented zoning designations using the Critical Realist framework of reality levels.
DATA	Building information with business locations and mobile phone data for daytime population volumes in the Helsinki region.	Location-based personal carbon footprint records with classified, detailed land-use data in five Nordic capitals.	Case study combining existing real-world data with experimental design information for impact comparison.
RESEARCH PURPOSE IN THESIS	The purpose is to quantitatively verify the plausibility of the key planning argument for high Gross Floor Area impacts.	The purpose is to isolate the impact of local zoning plans on residents' personal carbon footprints.	The purpose is to review why zoning and EIA are not aligned, and to examine the power of zoning to shape EIA themes in light of the carbon footprints of urban development.

Table 2.1.2 The role of the background articles B1 and B2.

	Publication B1	Publication B2
TITLE	*Density as an indicator of sustainable urban development: insights from Helsinki?*	*Assessing the livability within the 15-minute city concept based on mobile phone data.*
RESEARCH QUESTION	Quantify the reliability and pitfalls of density calculations as a meaningful indicator for urban development.	Can livability indicators derived from literature predict observed human activity patterns at different times of day?
METHODS	GIS analyses how the choice of unit (building vs. population grid) affects density calculations, and how different container sizes (buffered building polygons, grid cells, administrative zones) influence density values.	Grid-based Pearson correlation analysis applied to geographically weighted regression models for diversity indices derived from liveability indicators.

2.2 Quantitative methods

The quantitative methods developed and applied have been a key methodological outcome of the research and an important learning experience for me, given my background as a planner. For example, findings and lessons from the background articles (B1 and B2) led to the development of a technique that avoids recognised pitfalls in GIS-based research. Those errors commonly stem from careless data classifications and aggregations for analysis (often the so-called MAUP and UGCoP errors): MAUP stands for Modifiable Areal Unit Problem, a statistical bias in spatial analysis in which the results of a study change depending on the size and shape of the spatial units used to aggregate data (Openshaw, 1983). Article B2 elaborate on the scale of the biases in the context of urban planning in more detail. UGCoP stands for Uncertain Geographic Context Problem, which refers to the bias arising from the improper contextual relevance of the selected units or indicators used in analysis (Kwan, 2012). Avoiding both of these errors is crucial in city science, as urban areas often comprise a diverse and incommensurate range of geolocated features. Urban features emerge from several phenomena at different scales, ranging from unbuilt land for parks and infrastructure zones to apartment clusters of various typologies and business facilities, which may be built, unbuilt, occupied, or vacant despite local zoning efforts (as demonstrated in paper A1). A typical example of a contextual UGCoP error is the use of service counts as an explanatory variable for sustainable transit modes within the selected boundary. This often leads to circular reasoning, such as 'local services increase walkability' or 'infill development near (existing) services is sustainable'. The number or diversity of services is not a local feature but the result of features in a larger context: e.g., regional traffic network and the emergence of services and shopping malls in its specific nodes under the impact of real estate management strategies for monetary efficiency within the service networks (e.g., centralisation of health care facilities).

The quantitative methods used in the papers aim to avoid or minimise these errors by using as high-resolution data as meaningful, with zoning-relevant classifications and geographically scalable methods (Figure 2.1.1). The quantitative aggregation based on commensurate hexagon indexing was leveraged in the papers A1 and A2, both of which include quantitative correlation analysis.

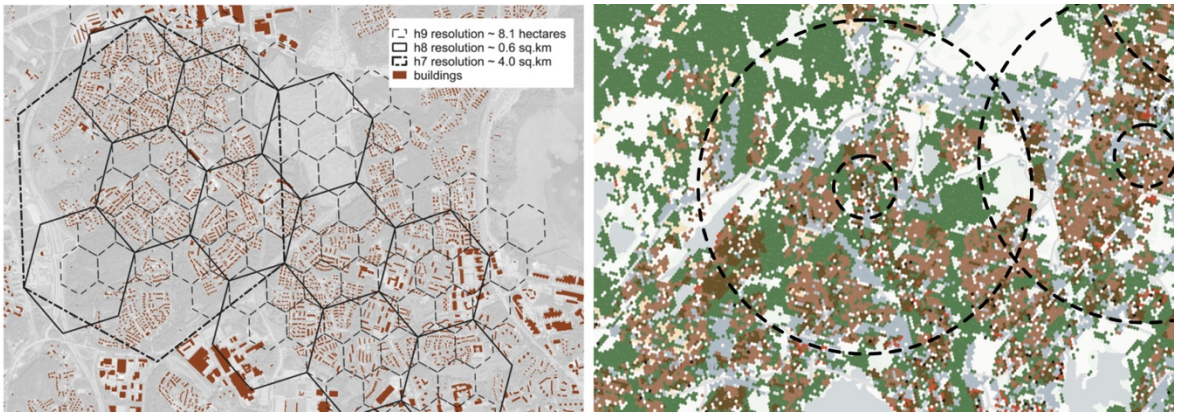

Figure 2.2.1 Illustrations of the hexagonal technique applied in the papers A1 and A2.

On the left, the correlation between urban services and Gross Floor Area in the buildings was aggregated similarly for each scale to minimise MAUP errors. On the right, the urban land-use delineations derived from the source dataset are reclassified to align with zoning

designation logic to minimise UGCoP errors. They are then disaggregated into hexagonal cells of equal size to ensure consistent measurement across scales at any location, using similar radii for the studied neighbourhood sizes to avoid MAUP errors. This enabled the calculation of correlations between residents' carbon footprint records and their local land-use coverages at various scales in a consistent manner. (See Papers A1 and A2 for more detailed explanations.)

2.3 Qualitative insights

The epistemological approach guiding the derivation of qualitative insights for future planning builds on the UGCoP error-avoidance strategy described in section 2.2: the approach to classify land use through the planners' own conceptual language – general zoning designations (land-use type and GFA volume). Such classification constitutes a *qualitative* step that precedes quantitative analysis, enabling interpretation of the results in relation to zoning practices that follow the same classification logic but in future planning contexts. Scientific philosophy in this relies on the Critical Realist view that even if the city is an open system, the empirical quantitative findings can be seen as a sign of the *causal power* of the analysed feature on the selected impact (carbon footprint) if the features (land-use) are classified in a contextually relevant manner in the given context (zoning).

In paper A3, the Critical Realism philosophy is applied more explicitly using its analytical framework of *reality levels* in a comparative case study, but without quantitative analysis. This enabled comparison of the societal mechanisms underlying zoning in the context of climate-friendly urban development. This required us to develop a case study approach combining real-world data with a hypothetical model. Rather than assessing a single planning solution, we elaborated on the impacts of its experimental *designations* with those of traditional ones. This required a pluralistic methodology, in which we treated the case study as a *thought experiment* (Flyvbjerg, 2006) to reveal mechanisms hidden within traditional regulatory practices, as Isaksen suggests when applying Critical Realism (Isaksen, 2016). Flyvbjerg emphasises case studies as tools for theory development, while Isaksen highlights the importance of theory-led pluralism in methodologies to reach explanatory depth, which Critical Realism seeks. The pluralistic and transdisciplinary approaches are essential for understanding the multidimensional nature of climate impacts in urban planning (Bhaskar, 2010). The outcome of such a study is a set of hypotheses for future research as illustrated in the Wheel of Science (Figure 2.1.1).

Table 2.3.1 Example of application of the Critical Realist framework for qualitative comparative analysis from Paper A3.

Domain	Traditional Zoning	Climate Zoning
Empirical	o Measurable, restricted physical development metrics (e.g., GFA as building rights) o Unpredictable and unmeasurable climate impacts (outside the scope of zoning)	o Unrestricted architectural volumes o Uncontrolled cityscape impacts o Predictable climate impacts (regulated via zoning designations)

Actual	○ Established real estate development practices prevail ○ Conventional economic valuation models apply ○ Supports traditional construction industry methods	○ Necessitates new valuation paradigms aligned with designated climate impact levels and the absence of predefined GFA rights ○ Requires new consultancy expertise to calculate compliance with zoning designations ○ Demands R&D to enhance construction industry capacity and align with new valuation expectations.
Real	○ Reinforces the existing capital-based real estate economy and its valuation logic ○ Preserves current power structures and economic relationships	○ Challenges traditional urban economic models, especially those related to financial markets and valuation logic ○ Promotes the emergence of new socio-ecological governance paradigms, expanding the role of planners)

3 Results

The detailed, high-resolution data, combined with contextualised methods, have revealed some controversial findings. For example, the finding that high Gross Floor Area (GFA) development, when facilitated by zoning plans, does not generate local services and urban liveability, which are key prerequisites for the sustainable transportation modes these plans aim to support (Article A1). Furthermore, the quantitative results from the Nordic case regions challenge prevailing assumptions about sustainability from two directions. On the one hand, high-density, efficiency-oriented zoning appears to fail to enable the low-carbon lifestyles argued for, instead reinforcing high-carbon behaviours through consumerism and increased travel. On the other hand, lower-density zoning, widely regarded as unsustainable, tends to predominate also in cities in locations where residents have lower carbon intensities and overall emissions, even when income and household types are controlled (Article A2). Additionally, the comparative case study analysis demonstrates that the current divergent roles of zoning plans and Environmental Impact Assessments (EIAs) could be reversed to achieve the much sought-after sustainable systemic changes (Article A3). The overall results are summarised in more detail in the following chapters 3.1 - 3.4.

3.1 Call for new metrics

The arbitrariness of density metrics in providing meaningful information for urban policies and planning was demonstrated in Article B1. Density is a concept with varied interpretations and mathematical formulations. This makes it an easily biased metric. Article B1 demonstrated that the metric's relevance shifts depending on variations in either the units (population, housing units, household, GFA, etc.) used to measure density or the ‘container’ (plot, block, zoning zone, neighbourhood, etc.) in which those units are measured. This is problematic because density, as a metric, often serves as both an end and a means, with geospatial biases explained in Chapter 2.2. The paper focused on explaining errors in density calculations (such as those noted in section 2.2), but did not question the sustainability of densification per se. However, a clear doubt emerged during the research, prompting the definition of research questions for the key articles A1 and A2.

Article B2 focused on the common planning goal called ‘liveability’ by measuring the correlation between the intensity of human activities measured using mobile-phone data, and literature-derived liveability indicators (diversity, density, proximity, accessibility) in the Helsinki region. This assessment framework did not focus on the complex phenomena of liveability as a human behavioural activity, but rather on the measurable urban features that the literature review identifies as prerequisite components for achieving liveable urban places. This ensured the method's construct validity in the context of urban planning, but also limits interpretations of the findings accordingly. The analysis did not find any location which would have had high human activity without any liveability features. However, the positive correlation between green area features and human activity in locations that lack the typical consumeristic urban features facilitated by urban design raises the important climate-

aware conclusion: green spaces, as an urban feature, can also be considered a land-use type for liveability goals.

Both background articles illustrate that there is a need to find non-biased methods to measure urban development data-based. The criticality of this need is rising as the requirement to track planned land-use sustainability quantitatively in new ways has recently been integrated in the EU Green Deal strategies for biodiversity and climate (e.g., COM(2021) 82 final, 2021; European Commission, 2020; European Environment Agency., 2025). The goal of these strategies is to *avoid density* and safeguard open natural areas, thereby preserving vegetation and soil in urban areas. This set of objectives stands in contrast to contemporary planning that pursues density. If both objectives and their measurement practices are maintained simultaneously, this may create pressure on operational planning to pursue both spaciousness and density simultaneously. In practice, this leads to an urban structure fragmented into overly dense blocks that require carbon-intensive construction methods and infrastructure, resulting in significant indirect impacts on both the climate and local living conditions. Hence, there is an acute need to enhance *quantitative* understanding of the impacts of zoning, as zoning is the key instrument used to legitimise development that policies, such as the Green Deal, seek to track.

The key outcomes from background articles (B1 & B2) are as follows:

- **Density is a distorting indicator:** Density is an error-prone indicator of regional development from the perspectives of sustainability and urban spatial quality. The findings in the paper B1 call for defining new metrics by which urban planning can be measured.

- **Non-commercial land-use can facilitate liveability:** Liveability can also be achieved by non-commercial land-use (e.g. parks). This was quantitatively evident in the study reported in paper B2, although commercial facilities tended to dominate the analysis.

3.2 High-density zoning for local services

Paper A1, *"Compact city and urban planning: Correlation between density and local amenities,"* sought quantitative insight into how urban density, as measured by GFA volume, correlates with the growth of urban amenities and liveability. The study used the Helsinki region as a case during the era of strong regional growth at the dawn of the millennium. The study reveals that while a clear correlation exists between residential Gross Floor Area (GFA) and urban amenities at larger geographical scales, this relationship significantly diminishes at the local, walkable neighbourhood level (Figure 3.2.1). The results suggest that urban amenities often cluster in locations different from where high residential density is planned and constructed, indicating a growing disconnection between GFA-based planning goals and actual amenity development.

We also analysed the correlation between the daytime population and GFA-based densities, separately for overall GFA and residential GFA (Figure 3.2.2). Daytime populations in the Helsinki centre and Vantaa were less correlated with residential GFA than with overall development, indicating that liveability is clustered more in non-residential areas. The correlation disparities are milder in the Helsinki suburbs and Espoo, areas characterised by a more multicentred urban structure. This indicates that the daytime population is more evenly distributed with residential development when there is no single dominant urban centre. Different results, especially from Vantaa, can be seen to verify this, as the Helsinki city centre area attracts a non-local daytime population far more than its peripheral areas, resulting in a stronger correlation with total GFA. Despite the differing historical foundations of the study areas, the trajectory of change in urban development after the millennium has followed remarkably similar patterns across the Helsinki city region for both the amenity growth and the daytime population.

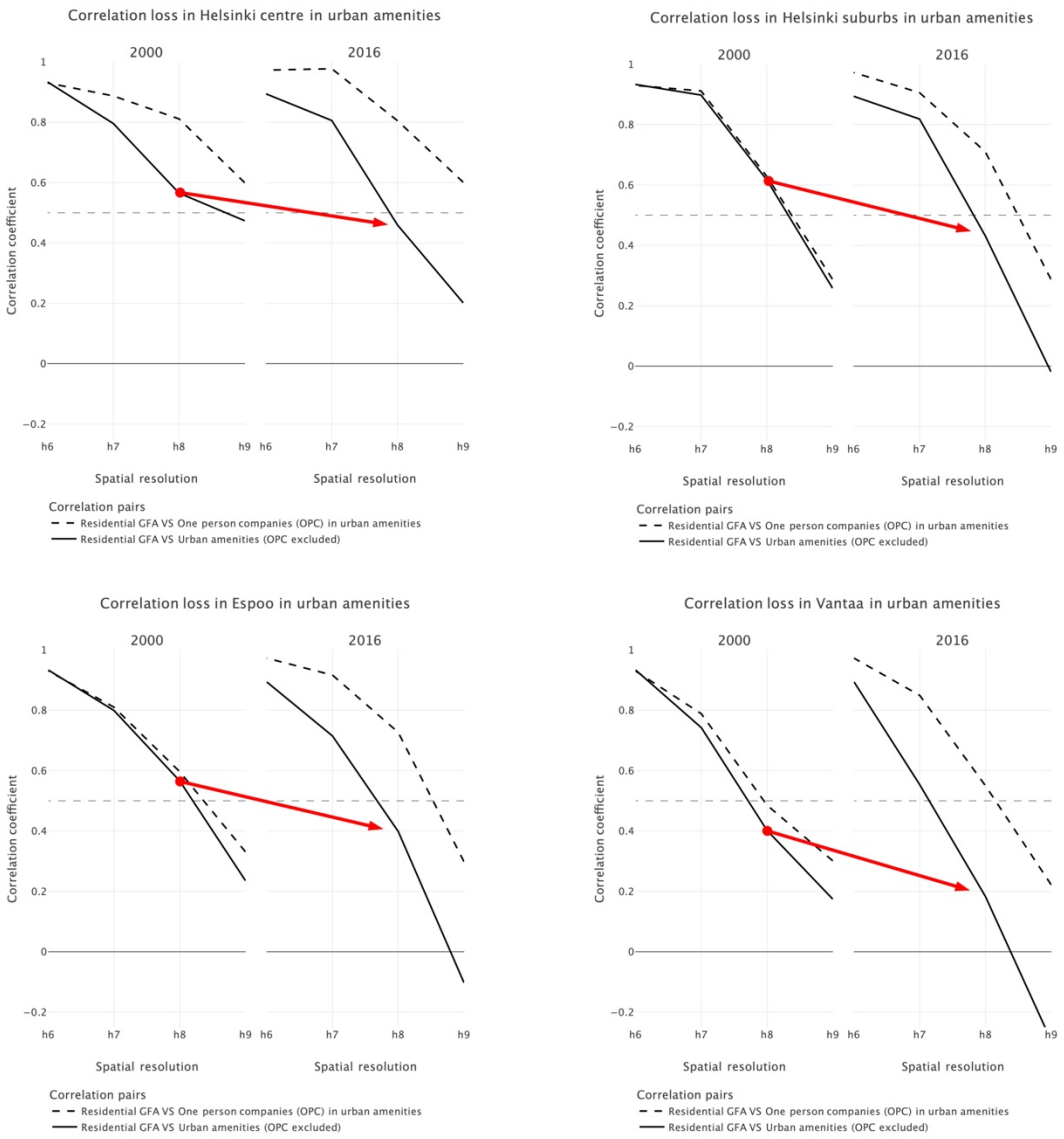

Figure 3.2.1 Correlation loss in amenities for sub-parts of the region: Helsinki city centre, Helsinki suburbs, Espoo and Vantaa.

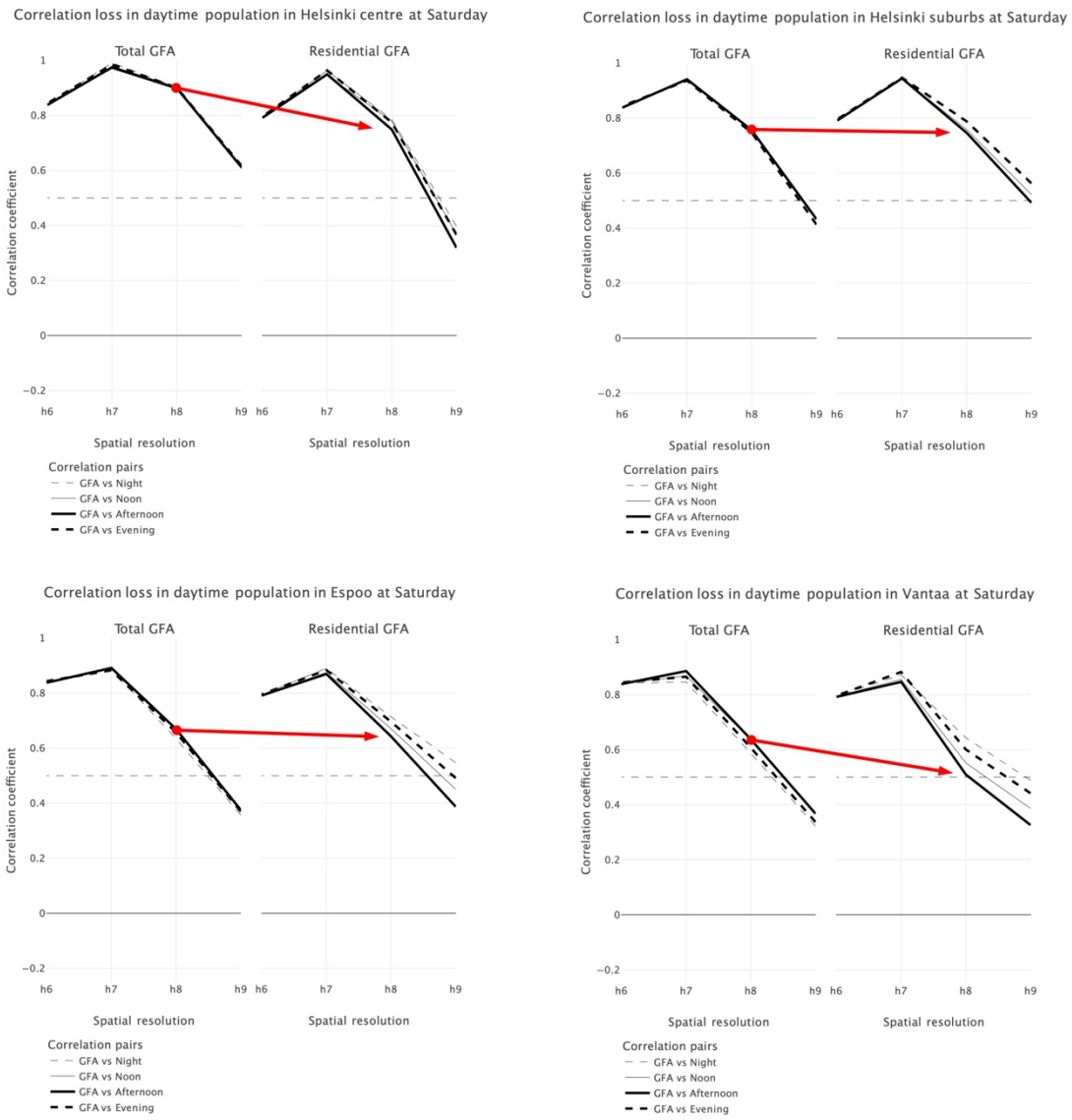

Figure 3.2.2 Correlation loss in the daytime population across sub-regions.

The key outcomes are as follows:

- **Shortcomings of compact city planning**: Urban amenities tend to emerge in locations other than those zoned for high-GFA development. The density of a larger urban structure is more relevant for amenity development than local GFA increases, as local correlations diminish even with regional growth. This suggests that high GFA zoning does not yield desired sustainability prerequisites for local living. The study concludes that if urban planning aims to foster local amenities and liveability, it should focus on broader urban development patterns rather than solely on high GFA in plan-making.

- **Need to refine the understanding of liveability**: Similarly to paper B2, but now more tied to planning, paper A1 questions whether liveability, when solely tied to consumer amenities, is a reasonable goal for public land-use planning, as it drives purely consumer-oriented lifestyles with high carbon intensities, which easily overshadow the mobility gains in scale.

3.3 Land-use and residents' carbon footprints

If high-GFA development rights in a compact form fail to meet the prerequisites for mundane local living, what potential do zoning regulations have to drive low-carbon urbanism? This question was addressed in Paper A2, *"Impact of Land-use Planning on Lifestyle Carbon Footprints."* In that, we investigated the correlation between neighbourhood-level land-use types and residents' lifestyle carbon footprints in Nordic capitals (Figure 3.3.1).

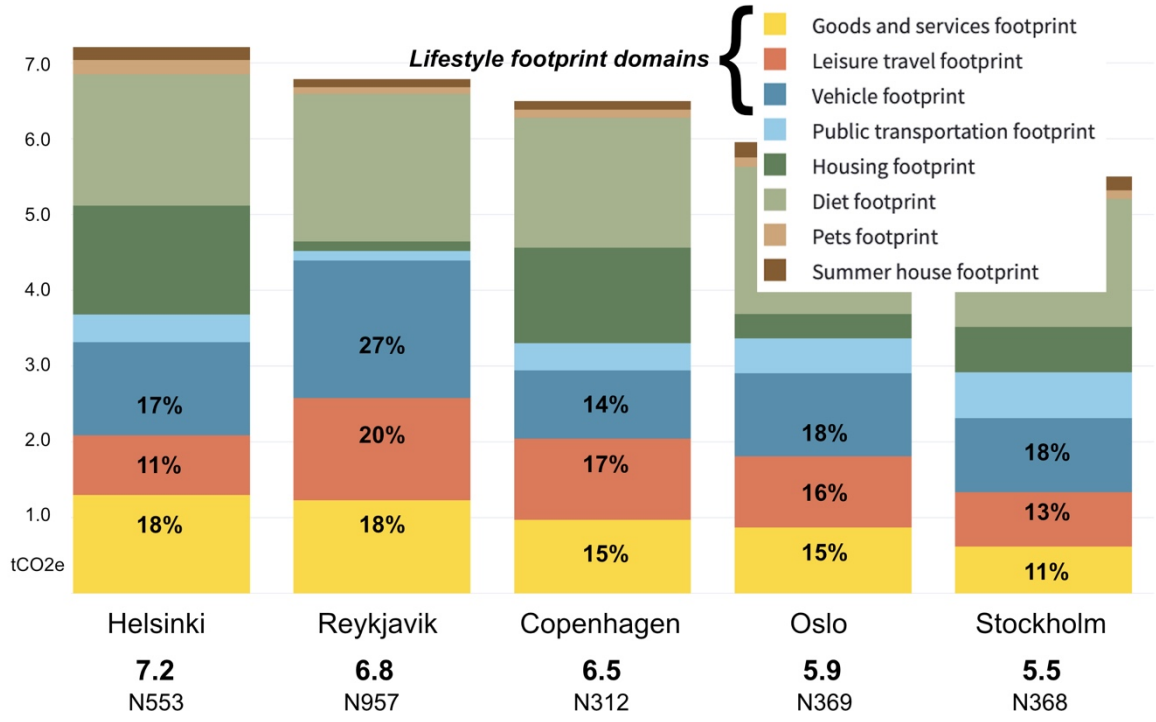

Figure 3.3.1 The carbon footprint per capita (tCO2e/a) in each case-city.

The per-capita carbon footprint values are divided into eight consumption domains. N-figures (e.g., N553) indicate the number of data points in a particular city sample filtered for this study. Per cent figures indicate the share of each lifestyle footprint domain within the city.

The findings show a positive correlation between urban land-use types and higher Leisure travel and Goods and services footprints, alongside an inverse (negative) correlation with Vehicle footprints. A novel insight is that this well-known pattern related to Vehicle footprint is not inverted in locations with less urban land use, whereas the footprints for leisure travel and goods & services are downscaled. Exurban environments, surprisingly, correlate negatively with both Vehicle footprints and Total footprints, thereby challenging common assumptions about the unsustainability of urban sprawl. Specifically, the Exurban land-use type demonstrates a consistent, linear negative correlation with Vehicle footprint within the 5 km radius study, a result not observed in the 1 km radius study. In highly exurban areas (within a 5 km radius), people may drive less frequently and consume less overall, resulting in a similar negative trend in total footprint. The differences observed between the

1 km and 5 km studies for other land-use types suggest that small-scale, local land-use solutions can have an impact, but the regional structure may overshadow them.

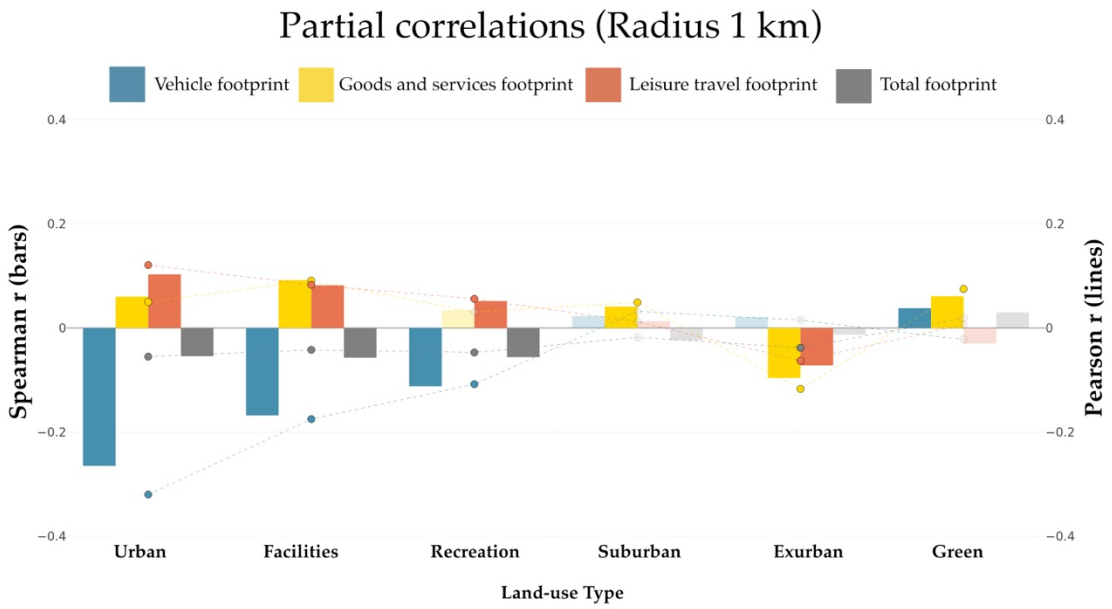

Figure 3.3.2 Spearman (bars) and Pearson (lines) correlations for target carbon footprints per land-use type in a 1 km radius in Nordic capitals (N 2559). Insignificant values greyed.

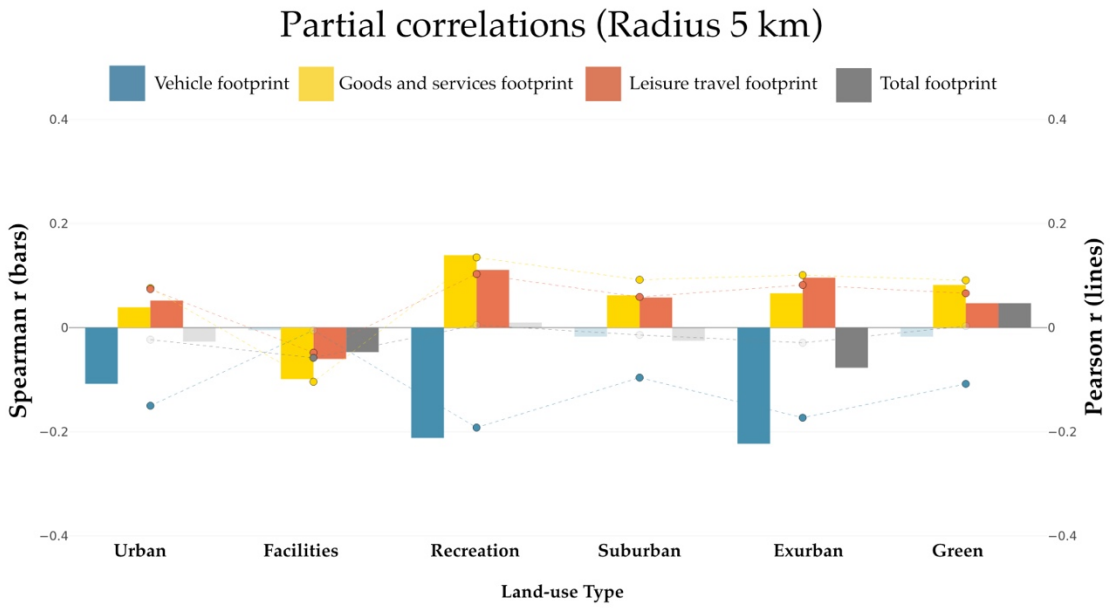

Figure 3.3.3 Spearman (bars) and Pearson (lines) correlations for target carbon footprints per land-use type in a 5 km radius in Nordic capitals (N2559). Insignificant values greyed.

The key outcomes are as follows:

- **Sustainability of urban sprawl**: The research confirms a well-known positive correlation between urban environments and higher Leisure travel and Goods and

services footprints, with an inverse correlation with Vehicle footprints. However, a novel insight is that exurban land use correlates negatively with both Vehicle and Total footprints. This suggests that life in exurban environments may have a slower pace, resulting in lower footprint levels despite higher car-dependency. Suburban living appears to balance between these extremes, showing no clear impact in either direction.

- **Rethinking planning for carbon neutrality**: The results provide suggestive evidence of the "causal power" that land-use can exert on urban lifestyles. The findings call for a revisit to the profession's historical mandate to adopt a more impact-based approach in plan-making practice.

3.4 Zoning as a tool for climate change mitigation

Papers A1 and A2 examined the climate impacts of typical zoning designations (GFA and land-use types) from two perspectives: through GFA & amenity development, and personal carbon footprints (PCF) they facilitate. Both approaches concluded that high-density zoning is irrational in the context of publicly pursued climate goals. The results rendered the highly powerful zoning instrument questionable in climate change contexts, leading to two afterthoughts. First, if urban planning as a public intervention were to be dismantled because it has turned against its mandate, it would likely be as great a loss as the dismantling of public healthcare due to poor management. Second, climate change mitigation calls explicitly for broad, systemic public interventions, and planning, as an existing institution, is precisely such a mechanism. It should therefore be fully utilised, and the zoning maps should be turned into a climate policy tool.

These thoughts led to defining the research setting for the paper A3 with a totally different approach. In Paper A3, "*Zoning for Zero: Critical realist analysis of urban plan-making for carbon-neutral cities*," we conducted a literature review to distil the underlying reasoning of the zoning paradigm and understand its disconnection from environmental impact assessments. Moreover, to concretise the present situation, we leveraged a Critical Realist analysis framework in a case study to analyse how realistically the same zoning apparatus could drive themes currently elaborated separately in EIA documents, albeit with a modest impact on zoning. The paper proposes a transformative "Climate Zoning" model that aligns zoning plans directly with climate mitigation goals by assigning legal limits to climate impacts. At the same time, non-binding assessments address traditional zoning concerns, such as development rights and per-capita metrics. Applying a Critical Realist framework to the case study, the paper demonstrates that the “inverted” zoning approach can instigate significant sustainable systemic changes in urban development, far surpassing the influence of isolated strategies or conventional EIAs. This paradigm shift necessitates new institutional capacities for climate mitigation, drives radical innovation in building design and materials, and encourages new real estate valuation approaches based on compliance with climate impact requirements.

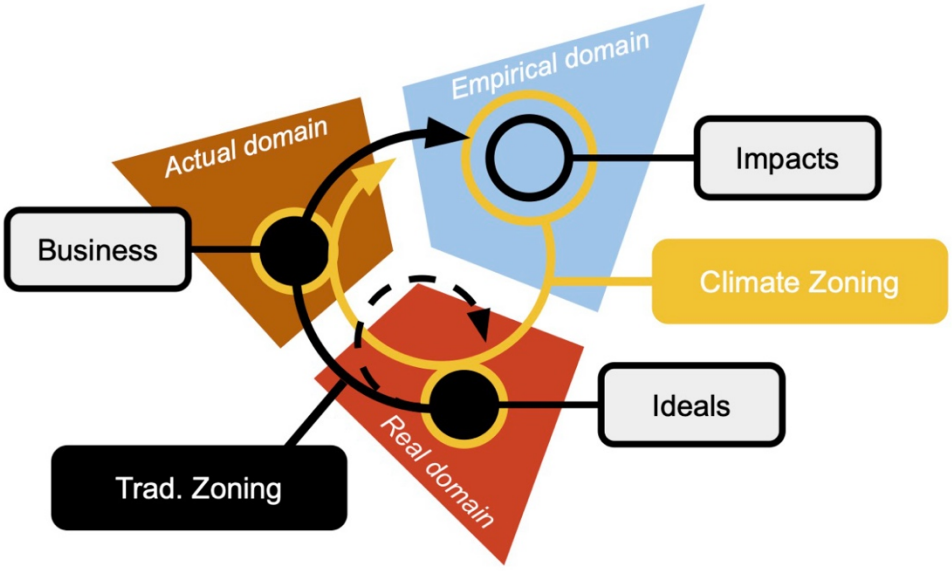

Figure 3.4.1 Concept graphic of the introduced impact-based Climate Zoning in Paper A3.

Traditional Zoning is based on hidden ideals within the Real domain. Publicly presented ideals (e.g., in architectural illustrations) hide the Real ideals (dashed line). Actual business is aligned with Real ideals, and results have corresponding impacts on the Empirical domain (the physical environment). Climate Zoning aims to reverse the process by starting with measurable goals for empirical impacts (e.g., carbon in the air or biodiversity on land) and articulating new ideals that businesses can align with, while leaving room for traditional zoning themes in the spirit of libertarian paternalism (Thaler et al., 2021).

The key outcomes are as follows:

- **Reimagining planning parameters creates multi-level systemic change**: The Climate Zoning experimental model deliberately excludes specific guidance on conventional GFA limit, thereby necessitating a fundamental shift in property valuation. While this approach shifts the focus of designations toward impacts, it does not resolve the trade-offs inherent in the reductive nature of zoning but merely alters their manifestation. Consequently, the Climate Zoning model requires analytically robust standards, similar to EU-guided Life Cycle Assessment (LCA) methods, to verify the impacts in a commensurate manner. This seemingly minor technical adjustment in designations has the potential to far exceed contemporary sustainability strategies and challenge existing economic models.

- **Ethical imperative**: The paper concludes that, given the Earth has surpassed most planetary boundaries, prioritising any objective other than climate regeneration in publicly funded planning is fundamentally flawed and unethical. The Climate Zoning model provides a conceptual example of how public urban planning institutions can be converted into impact-based regulation tools, similar to LCA requirements in building permits.

4 Discussion

The research design and methodological framework of this study evolved iteratively, informed by practical insights and observations gained from the work during the Background articles (B1, B2). Consequently, this methodological development represents a significant portion of the study's original contribution. While the novel thematic findings were derived from the Analysis articles (A1, A2, A3), the methodological innovations developed from the basis of experiences in background articles provided the necessary foundation. These methodological innovations also facilitated the formulation of specific research questions that would have been difficult, if not impossible, to address without the refined analytical tools developed during the process.

The research seeks to answer three overlapping research questions using mixed-methods grounded in the Critical Realist (CR) theory of science (Bhaskar, 2015). The research questions were as follows:

RQ1: *To what extent does the compact city paradigm in Nordic zoning meet its goals for the local amenities and low-carbon lifestyles it promises?*

RQ2: *How do specific land-use zoning designations correlate with residents' lifestyle carbon footprints when isolated from socio-economic factors?*

RQ3: *How can the legal instrument of zoning be reconceptualised to shift its role towards systemic climate mitigation?*

The questions were approached through a case-replicated mixed-methods rationale that connected empirical findings on indirect lifestyle carbon footprints with a CR-grounded process analysis of zoning plans as a tool for lowering these footprints. Article A1 established the initial empirical base in the Helsinki region, which was then tested for robustness in A2 across all Nordic capitals. The findings were further extended into the future through an experimental case study of a “reversed” zoning paradigm in Article A3 to analyse how realistically the same zoning apparatus could drive sustainability and climate change goals currently elaborated separately in EIA documents and GWP accountings.

4.1 Contribution and novelty value

The empirical core of this dissertation reveals a paradoxical tension in contemporary climate-aware planning: contrary to the prevailing compact city dogma, low land-use density does not increase residents' lifestyle emissions; rather, it seems to reduce them. This finding questions the contemporary institutional understanding of low-density impacts on total lifestyle carbon footprints (European Environment Agency. and Swiss Federal Office for the Environment (FOEN)., 2016; UN Habitat, 2014). It also offers a more nuanced view of urban GHG-emission studies that have found traditional mobility differences between inner-city and suburban residents (Ala-Mantila et al., 2014; Chen et al., 2019; Heinonen et al., 2013; Ottelin, Ala-Mantila, et al., 2019).

The methodological innovations in data analysis successfully move beyond the dualistic urban-suburban dichotomy. This revealed insights that had been obscured in many earlier studies that followed the dichotomy: The research reveals that the transition of Vehicle carbon footprint-based sustainability within the city region is not linearly associated with urban density. Simultaneously, the results confirm the more familiar "other pole" of the tension: high-density land-use correlates positively with increased consumption and travel footprints, while the correlation with car use remains negative. The former aligns with the referenced studies, while the latter aligns with a common understanding among Nordic urban planners (e.g., Berghauser Pont et al., 2021).

These findings are particularly significant in an urban planning context because the dataset comprises exclusively urban regions (excluding rural areas) and the analysis is conducted at the neighbourhood scale, where the influence of zoning is more straightforward. The findings question the typical sustainability arguments related to compact urban land use and sprawl, flipping the sustainability sides between them. This flip clearly calls for further research with a wider scope by integrating traditional per capita infrastructure implementation GHG accounting, with their indirect impacts, into the same (dataframe) table. By reflecting these notions against the research questions, the following theses can be concluded under the research question themes:

4.1.1 The gap between the goal of density and reality

The dissertation demonstrates that the climate burden of urban development originates at the local zoning level but often fails to support the promised local economic development and life. The results suggest a systemic failure in the current paradigm:

- **Increased outsourced consumption:** Higher local land-use density appears to drive up consumption levels. But instead of supporting local living through services, high-density seems to shift the consumption further from the immediate neighbourhood, paradoxically increasing the need for travel. Hence, the "means" (densification) do not align with the sustainability "ends" (lifestyle emission reduction), revealing a gap between zoning goals and actual carbon outcomes.

These conclusions first arise as hypotheses within the research, supported by articles B1 and B2. The hypothesis was verified in the Article A1 study, which revealed that strong economic growth and an increase in urban services in the Helsinki region during the study period clustered in locations different from those of Gross Floor Area growth, facilitated by zoning plans (Figures 3.2.1 and 3.2.2). The finding that high-density zoning often fails to deliver the promised *prerequisite* for a low-carbon lifestyle is strongly corroborated by related European research, which has stated that, while the compact city model successfully reduces direct emissions from housing energy and private driving, these gains are offset by higher indirect emissions associated with urban living (e.g., Ala-Mantila et al., 2023; Ottelin, Heinonen, et al., 2019; Wiedenhofer et al., 2018).

4.1.2 Zoning designations and lifestyle emissions

By isolating land-use effects from socio-economic variables, this research provides a nuanced understanding of how specific land-use designations align with lifestyle carbon footprints, using data from all Nordic capitals.

- **The power of lighter zoning:** While density successfully reduces car dependency, this benefit is offset by other lifestyle factors that account for a larger share of the total footprint (Figure 3.2.1). This pattern was inverted only with respect to consumption – not vehicle use – when moving from urban to exurban land use. The result aligns with recent findings that low-carbon construction methods are often technically infeasible within high-density urban plans, which call for lighter zoning to facilitate the green transition in the construction sector. This synergistic nature emphasises the power of zoning to mitigate both direct and indirect urban emissions.

These conclusions, derived from Article A2, constitute the most important results of this research in the context of urban planning. Urban plans do not specify the details of building or infrastructure implementation design, for which GWP impacts are tracked using established LCA accounting protocols during the building permit phase, as illustrated in the introduction. Instead, the plans legitimise the "landscape of the possible" at which the implementation phase operates. The 'landscape' may exclude highly mitigative design solutions (e.g., unbuilt soil and tall trees within the plot, or biogenic materials for carbon sequestration), leaving LCA accounting in *a minor role* in the context of climate change and the institutional goals it is intended to address.

The observation that urban land-use correlates with lower private vehicle emissions, which simultaneously correlate with higher emissions from leisure travel and the consumption of tangible goods, aligns with nuanced breakdowns of European-level household carbon footprints found in the literature (Czepkiewicz et al., 2018; Ottelin, Heinonen, et al., 2019). The discussion on lifestyle, often attributed primarily to affluence, gains a new dimension from Article A2 through two perspectives. First, by controlling for income and housing type, the study demonstrates that the rise in carbon-intensive urban living is also driven by facilitated land-use patterns nearby. Second, by focusing exclusively on urban regions (Nordic capitals) and omitting rural data, the research verifies the latter that land-use decisions can affect the sustainability of urban life. The results effectively move the conversation beyond the typical urban-rural dichotomy to show how internal city structures – defined by zoning documents – dictate indirect environmental outcomes.

From a land-use planning perspective, these findings are both significant and encouraging. They resolve the prevailing tension between justifying the high direct carbon emissions of carbon-intensive, high-density construction and the intended per-capita indirect sustainability benefits. Planners no longer need to tolerate carbon-heavy construction methods as a prerequisite for supporting low-carbon urban lifestyles. Instead, climate-aware zoning exhibits a powerful synergy with low-emission building practices. This is particularly relevant for new developments and urban regeneration projects in which entire districts are redesigned and rebuilt from the ground up, as these projects contribute most to the construction industry's future carbon load (Talvitie et al., 2025; Zhong et al., 2021).

4.1.3 Reconceptualising zoning for mitigation

The qualitative case-study suggests that the zoning designation logic can be reconfigured to move beyond the binary of "dense vs. sprawl". To act as a tool for systemic climate mitigation, zoning must be reconceptualised to:

- **Prioritise the impacts of outcomes:** Instead of focusing solely on technical GFA or density metrics, zoning should be evaluated by its capacity to support low-carbon urban development and to facilitate less carbon-intensive lifestyles. Planners must recognise that lower-density urbanity can be a potent climate tool when it enables low-energy construction and lifestyles without consumption amenities (e.g., “parks-as-a-service”). This shifts the focus from physical compaction to the functional reduction of the total carbon footprint, acknowledging that the most "efficient" land use is the one that results in the lowest emissions per unit of *time*.

The role of Article A3 was to extend the empirical findings of the present towards “the possible” in the future in which planning operates. By leveraging the Critical Realist analysis framework of reality levels (domains), it nudges the methodological dialogue towards the Real domain – the societal structures and the history of the rationales behind the contemporary planning paradigm. By doing so, Article A3 reveals that the zoning instrument can be used as such to mitigate both direct and indirect GHG emissions stemming from land use. By transforming the zoning map into a tool for climate impact management, we can achieve cross-sectoral sustainability benefits that address both the direct and indirect emissions of the construction sector. The built environment has significant, underutilised potential to act as a carbon sink through the use of bio-based materials and the preservation of soil organic carbon (Kuittinen et al., 2023; Malabi Eberhardt et al., 2024). Furthermore, the impact-based designations force urban design to better account for local ecosystems. The sustainability of both planning and construction solutions depends on their ability to generate "situated" approaches that adapt to specific ecological contexts rather than relying on the application of universal models for outcome (Haila, 2000).

4.2 Validity and reliability

The research design in this work is grounded in a case-replicated mixed-methods rationale (see Chapter 2.1) within a theoretical framework of the Critical Realist philosophy of science (Bhaskar, 2015). This design was heavily inspired by Roy Bhaskar's and Peter Næss´s arguments about CR's capacity to analyse highly “non-Humean” and interdisciplinary processes, particularly in urban planning and climate impact research (Bhaskar, 2010; Næss, 2015). In this mixed-setting, the validity and reliability issues are at two levels – the empirical and the interpretive – but the strategies to ensure them are tangled together within the research design, which is grounded on *case-replication* logic inspired by Flyvbjerg (2006) and Eisenhardt (1989).

Following Eisenhardt’s framework, in which each case serves as a distinct analytic experiment on the same phenomenon (Eisenhardt, 1989), Article A1 (case Helsinki) and Article A2 (case Nordic capitals) function as replications that confirm that the "zoning dispositif" consistently fails to generate low-carbon functionality in cities. The article A1 examines the phenomenon from a top-down planning perspective, while A2 presents a view from the citizen perspective, yielding similar results. In particular, the empirical finding that exurban zones in cities exhibit lower lifestyle carbon footprints (Article A2) constitutes the rigorous observation required to falsify the universal validity of the contemporary density-based sustainability paradigm (following Flyvbjerg, 2006). Furthermore, by treating the zoning model comparison in Article A3 as a Flyvbjerg´s "critical case", the comparison demonstrates the *potential-side* of the zoning instrument by applying the same planning

ontology with analytical framework (Critical Realism) used to analyse the existing model in Articles A1 and A2. Together, the different cases exploring the same theme create a "thick" narrative, which Flyvbjerg emphasises. Following Eisenhardt (1989), this approach creates a robust, generalisable setting by retaining similar zoning-level relationships that are replicated across cases, rather than focusing on the unique details of individual cases. This ensures that the conclusions regarding zoning's causal power in this context are theoretically transferable and validated by the data. Across the cases, this ensured that both the contextual validity and reliability were established through domain-specific data handling and statistical robustness. They rest on methodological *coherence* and active *verification* strategies (Morse et al., 2002), both of which are important in mixed-methods research that combines empirical statistical data and qualitative insights (Maxwell, 2010). The coherence and verification were achieved by applying geospatial statistical methods in a similar manner in articles A1 and A2. In addition, verification was strengthened within each case on a cyclic Exploratory Data Analysis (EDA) approach, repeated across both articles, to identify patterns without a predetermined hypothesis. Contextual coherence in research data was ensured by using study resolutions relevant to plan-making, and by applying zoning-related classifications when aggregating data points for correlation calculations (see Chapter 2.1). The same contextual ontology (zoning designations) was examined in Article A3, although the analysis was qualitative. This *contextual complementarity* between the studies, from data preparation and analysis to theoretical future-oriented interpretation, strengthens both the explanatory validity and the practical relevance of the study.

The mix of validation rationale can be summarised as follows:

a) Quantitative analysis and construct validity

Articles A1 and A2 employ replication logic (Eisenhardt, 1989). By extending the analysis from a single context (Helsinki) to a broader set of contexts (Nordic capitals), the design ensures that the observed urban planning outcomes are not idiosyncratic but exhibit internal generalisability (Maxwell, 2010). Data source quality checks, outlier thresholds, and domain-specific classifications were verified in a cyclical EDA process using automated analysis methods (Python geocoding) to ensure high *construct validity* in the planning context. The statistical methods themselves rely on standard validation metrics (e.g., p-values) produced by the selected correlation methods (see articles A1 and A2 for more details).

b) Qualitative analysis and epistemic validity

Interpretations in Articles A1 and A2, and the application of the Critical Realist analysis framework in Article A3, bridge the applied epistemology from the quantitative tradition to the normative qualitative tradition integral in urban planning. The use of land-use classifications aligned with planning practice terminology increased the qualitative interpretability of the results. The partial consistency with earlier lifestyle carbon footprint research (Chapter 4.1) can be interpreted as supporting the reliability of the results, which also yield novel findings.

4.3 Limitations

Zoning acts as a highly reductive instrument because it is inherently based on trade-offs. This creates a clear limitation to using zoning to drive specific lifestyles on a larger-scale, as many urban processes originate from factors outside the planning sphere. Despite these limits, influencing how a city functions and how people live has been the core goal of urban planning, particularly in arguments for sustainable modes of transport, as explained in articles A1 and A2. The extreme reductiveness, especially in housing, has a decisive impact on citizens' lives locally, while also having a limited impact on urban development on a larger scale. The articles A1 and A2 sought to quantify that impact from a user perspective, focusing on carbon footprints by isolating them from typical non-planning factors, such as affluence and housing type. In addition, the experimental paradigm flip illustrated in Article A3, which focuses on indirect impacts other than lifestyle, relies similarly on the very same reductiveness when redirecting power toward climate issues. Hence, given this retained contextual scoping, all studies have inherited the "regional limitations" associated with land-use planning when retaining contextual and construct validity toward zoning plan-making.

The combination of methods and strategies outlined to ensure reliability mitigates limitations arising from data sources, but not those related to the depth of analysis. The thematic scope of this thesis is highly transdisciplinary, meaning that the results and interpretations relate to several professions and institutions associated with urban planning as well as to academic disciplines within urban studies. This creates epistemic limitations that are most evident in the Critical Realist analysis presented in Article A3. However, the depth of analysis in Critical Realism is achieved not by adding more data and depth at the same level (or discipline), but by integrating different kinds of knowledge, even if they, as such, cannot achieve the siloed depth (Bhaskar, 2010). In this sense, the depth of CR is bottom-up, oriented toward a less tangible human reality, rather than top-down, which focuses on increasingly detailed empirical metrics. These limitations are explained and listed by the key articles in Table 4.3.1.

Table 4.3.1 Recognised limitations in the analysis articles (A1,A2,A3).

Article	Recognised limitations
Compact city and urban planning: Correlation between density and local amenities	Research used anonymised, aggregated mobile phone data from the Helsinki metropolitan area for the daytime population. This data combines local mobile phone records with those of regional and international visitors, which prevents interpreting results in relation to local Gross Floor Area (GFA) with the same validity as with urban services. This feature of data used in the research is elaborated in the paper in more detail.
Impact of Land-use Planning on Lifestyle Carbon Footprints.	Limitations relate to the original classification logic used in the land-use data. Urban Atlas[2] provides a consistent classification that aligns well with Nordic zoning traditions. However, this is also its downside, as it confuses density-related classes with combined land-use functions, hindering the interpretation of the potential impact of mixed-use development (i.e., different

[2] https://land.copernicus.eu/en/products/urban-atlas

	land-use types within the same zone designations). Similar precision issues relate to the carbon footprint calculations regarding possible survey respondents' self-estimation errors, which limit the accuracy of interpretations (compared to broader comparisons across the urban-rural continuum). These issues are elaborated in more detail in the paper.
Zoning for Zero: Critical realist analysis of urban plan-making for carbon-neutral cities	The study in Paper A3 yields a set of hypotheses for future research. The limitations are related to the depth of analysis possible within the scope of a single article, constrained by the journal and the available peer reviewers. This is a common limitation of publication-based scientific work, recognised as hindering climate impact research in general (LeGates and Stout, 2020).

5 Conclusions

The higher-level practice-oriented conclusion can be crystallised into the following suggestion: *To follow its original role as an institutional tool to manage unhealthy externalities of city development, and to contribute positively to the contemporary climate change mitigation needs, zoning must first free itself from the constraints of per capita–based efficiency calculations as the dominant foundation for planning solutions.*

At its core, this means applying impact-based urban design thinking in a more situated manner, as modernists tend to do (e.g., not through predefined normative models of urban form). Today, situated thinking is supported by high-resolution urban datasets that are commonly available and powered by fast computational capabilities (e.g., machine learning to recognise patterns in urban data). In parallel with this "situational step", the development of impact-related designations, as analysed in Article A3, is highly recommended to fully leverage the power of zoning for climate concerns.

The lack of institutional clarity and the deregulation of land-use laws in the Nordics, as noted in the introduction (chapter 1.2), call for the refactoring of zoning activity in line with global-level policies. There is divergent development in land-use administration in the EU: on the one hand, the legal power of the traditional zoning apparatus has been narrowed to facilitate only GFA rights by simplifying plan designations in the spirit of deregulation and private freedom. On the other hand, paternalism has advanced to EU-level directives that guide local laws on building permits, requiring stricter climate-impact controls through detailed LCA accounting. The result is a burden on developers, but the impact remains low because of divergent paradigms in contemporary zoning, as explained in the introduction. The conclusions derived from this research call for refactoring the zoning in line with EU-level directives to help the construction industry achieve the required project-based reductions, while retaining crucial soil for regenerative urban nature.

This is a relearning process for all. Politics and practitioners must relearn how to apply land-use *decentralisation* to manage urban growth sustainably – not through high-volume infill in traditional centres, but by balancing growth regionally. This shift aligns directly with the EU directive, which introduces mandatory calculation of Global Warming Potential (European Commission, 2024) and addresses the challenges identified at the beginning of the introduction chapter. Situated analytics can improve the accuracy of early-stage LCA assessments (see e.g., Präger et al., 2025) while they can also serve as a missing "agility link" between climate policy and fast-paced practical land-use planning – a challenge recognised also by the EU when seeking higher impact of GWP assessments (European Commission, 2024). The idea of the GHG-accounting scope 4, referred to in the introduction, expanding the GHG accounting towards *external* impacts, is highly recommended in this sense, as it shifts the accounting exercise more towards an environmental governance instrument, as noted by De Giovanni (2025). This impact-based thinking applied to urban planning will open up a new bottom-up perspective on urban development, illustrated by a conceptual graph that connects the *impact* of the established planning density metric (FAR) to the increase in the EU climate metric (GWP) in a transdisciplinary manner (Figure 5.1).

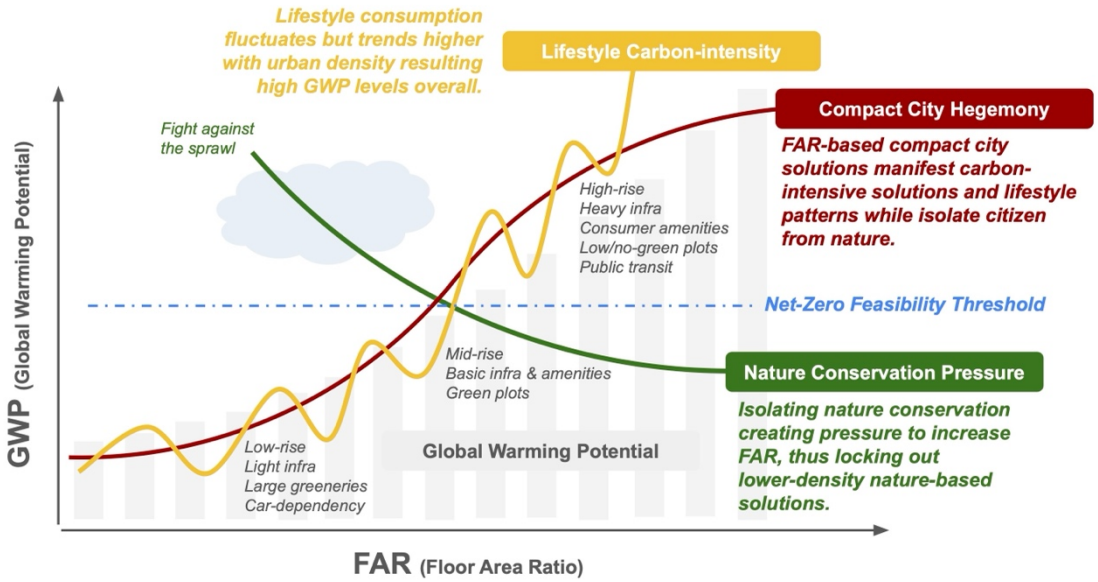

Figure 5.1. Illustrative summary of the climate dynamics of the urban planning discourses referred to in the research as a graph between zoned FAR and GWP generated by facilitated development.

Measuring the external GWP impacts of urban planning solutions as an environmental governance action within the design process echoes early 20th-century regional planning ideals, while updating them through digital spatial analysis and impact-oriented policies. This aligns with the seasoned planning scholars Michael Batty and Stephen Marshall, who have underlined that there is an urgent call for "new physicalism" in planning to address contemporary sustainability issues that stem not only from processes but from the outcomes –the blueprint plans (Batty and Marshall, 2009).

From these grounds, I will conclude the practical recommendations for politics, practitioners, and academia as follows:

For Academia: Systemic change in the technical-flavoured profession, described by Geels as a socio-technical transition (Geels, 2019), redefines both governance and market competence. To leverage these possibilities, a transdisciplinary research theme concerning the sustainability *criteria of construction financing* is proposed. This must include examining property valuation models alongside the climate change mitigation potential of zoning, with a focus on external impacts. City science scholars similarly require higher transdisciplinarity and prediction capabilities. For example, GHG, GWP and LCA research should leverage *Urban Planning Data* ("UPD") – zoning designations as a data source to predict sustainability *earlier* in the development process, long before construction begins. For example, by using scientifically validated *proxy metrics*, evolving GWP analysis can shift its focus from precise material databases used in LCA analysis toward actionable zoning mandates that proactively enable low-carbon development.

For Politics & Practice: Legislation must recognise land-use zoning as a primary tool for public intervention within the Nordic eco-welfare state, driving the systemic changes

required by modern environmental strategies. By reframing zoning back as a main regional governance tool, planners can maintain urban compactness where it is healthy, while utilising lower densities to facilitate low-emission construction that reduces reliance on carbon-intensive materials. This shift creates opportunities for climate-aware development across broader regions. Combined with traditional design solutions (plots with lower building rights), this approach also allows small- and medium-sized developers to compete in the city regions while expanding the market for emerging data-driven services such as evolving Global Warming Potential (GWP) and Life Cycle Assessment (LCA) consulting.

With these recommendations, I hope that my doctoral studies, synthesised in this dissertation, can serve as an inspiring path for future planners, politicians, and researchers to take seriously the future we build with our everyday decisions.

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Articles

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