Urban structure and sustainable transport

Exploring the relationship between urban structure and travel behaviour and the role of urban planning in Northern Europe
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Abstract

This PhD study explores the relationship between urban structure and travel behaviour and the role of urban planning in promoting more sustainable travel patterns.

The study conceptualises the role of urban planning by means of a multiple-case study of the three medium-sized Northern European cities, Eskilstuna, Turku and Tartu, that was conducted based on qualitative methods.

Further, the study investigates the relationship between the urban structure of people’s living environment and their travel behaviour by integrating daily modality styles (work and leisure), and weekend and holiday travel behaviour in a comprehensive analysis. Moreover, the phenomenon of compensatory leisure travel is addressed. For this purpose, a questionnaire survey was carried out in an urban district (Østerbro) of central Copenhagen and in a small town (Borup) in the commuter belt of Greater Copenhagen.

The study achieves a comprehensive understanding of travel behaviour and qualifies the role of urban structure in relation to further determinants. The influence of urban structure is largely limited to daily travel (bounded trips). Beyond urban structure, other determinants such as socio-economic factors, personal preferences and lifestyle, which are partly reflected in residential choices, have a significant influence on travel behaviour. This becomes particularly evident in weekend and holiday travel (non-bounded trips). Additionally, summer cottage use among city dwellers indicates some sort of compensatory leisure travel.

Consequently, urban planning can optimise urban structure and cooperate in transport planning, but structural adaptations of travel behaviour require also the involvement of higher tiers of policymaking.

Keywords: compact city, compensation hypothesis, leisure travel, mobility styles, residential location, transport energy use, urban form, urban development
Summary

Transport is responsible for one third of the energy consumption and one quarter of the greenhouse gas emissions in the European Union. Although technological improvements have fallen short of inducing the required reductions, transport is still predominantly the subject of a technology debate. On the contrary, the potential for structural changes in travel behaviour has not been sufficiently exploited yet. This PhD study addresses the interface between urban planning and structural changes in travel behaviour, which is linked to the concept of urban structure.

Urban planning is commonly guided by the assumption that dense and compact urban structure facilitates more sustainable travel behaviour. However, a comprehensive diagnosis needs to incorporate a broader set of determinants, such as socio-economic factors, personal preferences and lifestyle, whose influence possibly increases when it comes to non-bounded travel, such as weekend trips or holidays. Against this background, the study pursues three objectives: Firstly, the study conceptualises the scope and key framing conditions for urban planning, especially regarding transport planning. This is achieved by means of a qualitative approach that comprises a literature review and a multiple-case study of three medium-sized cities in Sweden, Finland and Estonia.

Secondly, the study engages in an in-depth analysis to explore the relationship between the urban structure of people’s living environment and their travel behaviour. For this purpose, a questionnaire survey was conducted in a dense urban district (Østerbro) in central Copenhagen and in a small town (Borup) in the commuter belt of Greater Copenhagen. The analytical approach integrates daily travel patterns (‘modality styles’) with weekend and holiday travel and adds a focal point by looking into the phenomenon of ‘compensatory leisure travel’.

Thirdly, the findings are synthesised to develop implications for urban planning and recommendations for changing travel behaviour as part of a sustainable urban development agenda.

The overall findings confirm that certain features of urban structure can facilitate, but not constitute, sustainable transport. Urban planning is in this regard often limited to optimising existing urban structure by implementing accompanying measures, such as public transport systems. Moreover, cities have to be considered with their functional relations, which are, for instance, expressed in regional transport, which calls for cooperation and coordination across municipal borders.

Further, the findings indicate that urban structure constitutes predominant modality styles – cycling in the urban district and car use in the peri-urban small town. More extensive weekend and holiday travel as well as plane use among city dwellers suggest once again a link with urban structure, which must, however, not hide the influence of socio-economic factors, personal preferences or certain lifestyles that are also expressed in residential choices. Evidence for compensatory leisure travel is only found in relation to weekend trips to summer cottages among city dwellers. Thus, the influence of urban
structure cannot be deduced directly from differences in travel behaviour between different residential locations.

In summary, urban structure and, hence, urban planning has an important role in achieving structural adaptations of travel behaviour. However, different domains of travel (daily work and leisure, weekend trips, holidays) underlie different explanations that reflect the interplay of a broad set of determinants. Consequently, limitations of urban structure and urban planning are unfolded and comprehensive approaches for understanding travel behaviour are advocated in this study without dismissing urban planning from its responsibility to engage in the challenge of changing travel behaviour within its capacities.

The PhD study was co-funded by the EU-FP7 project PLEEC – “Planning for energy efficient cities” (EC-FP7, GA no. 314704). Paper I and II are based on material and data collected in the project.
Resumé (Danish summary)

Transport står for en tredjedel af EU’s energiforbrug og en fjerdedel af den samlede udledning af drivhusgasser. Selvom teknologiske forbedringer ikke har afstedkommet de nødvendige reduktioner, er transport i overvejende grad genstand for en teknologidiskussion. Potentiale for strukturelle ændringer i befolkningens transportadfærd er derimod endnu ikke blevet udnyttet tilstrækkeligt. Dette Ph.d.-studie behandler grænseflader mellem byplanlægning og de strukturelle forandringer i transportadfærden, som knytter sig til begrebet bystruktur.


For det andet foretager studiet en dybdegående undersøgelse af forholdet mellem byens struktur og indbyggernes transportadfærd. Til dette formål blev en spørgeskemaundersøgelse udført blandt beboere i et tæt bykvarter (Østerbro) i det centrale København og i en mindre by (Boru) i det storkøbenhavnske pendlerbælte. Den analytiske tilgang integrerer daglige rejsemønstre (‘modality styles’) med weekend- og ferrierejser samt tilføjer et fokuspunkt ved at kigge ind i fænomenet ’kompenserende fritidsrejser’ (‘compensatory leisure travel’).


Endvidere indikerer studiets resultater, at bystrukturen skaber særligt fremherskende modalitetsstile (‘modality styles’) – cykling i den tætte by og bilkørsel i den peri-urbane mindre by.

Byboers mere omfattende weekend- og ferrierejser samt flyrejser understreger atter en sammenhæng til bystruktur, hvilket dog ikke overskygger betydningen af socioøkonomiske faktorer, personlige præferencer eller visse livsstile, som også er et udtryk for valg af bosted. Dokumentation for kompenserende fritidsrejser kan kun findes blandt byboeres weekendture til sommerhuse. Betydning af byens
struktur kan således ikke direkte udledes af forskelle i transportadfærden mellem boligområdernes beboere.
Sammenfattende har byens struktur og dermed byplanlægning en vigtig rolle at spille i opnåelse af strukturelle tilpasninger af transportadfærden. Dog ligger der forskellige forklaringer bag de specifikke rejsedomæner (dagligt arbejde og fritid, weekendture og ferier), som afspejler samspillet mellem et bredere sæt afgørende faktorer. Som følge heraf er begrænsningerne for bystruktur og byplanlægning udfoldet, og en helhedsorienteret tilgang til transportadfærd anbefales, dog uden at afskrive byplanlægningen sit ansvar for at deltage i udfordringen med at forandre transportadfærden indenfor egen kapacitet.
Ph.d.-studiet er støttet af EU-FP7 projektet PLEEC – “Planning for energy efficient cities” (EF-FP7, GA nr. 314704). Artikel I og II bygger på materiale og data insamlet i projektet.
Zusammenfassung (German summary)


Vor diesem Hinter grund verfolgt diese Arbeit drei Zielsetzungen: Erstens werden Handlungsspielräume und Rahmenbedingungen für die Stadtplanung, insbesondere in Bezug auf Verkehrspl anung, abgebildet. Dies erfolgt mittels eines qualitativen Ansatzes, der eine Literatursauswertung sowie eine Fallstudie von drei mittelgroßen Städten in Schweden, Finnland und Estland umfasst.


Drittens werden die Erkenntnisse in Hinblick auf Konsequenzen für die Stadtplanung und auf Empfehlungen zur Veränderung von Verkehrsverhalten im Rahmen einer nachhaltigen Stadtentwicklung zusammengeführt.


Es wird weiterhin aufgezeigt, dass Stadtstruktur die Bildung von Modalitätsstilen ('modality styles') prägt: Radfahren im Innenstadtbezirk und Autofahren in der stadtnahen (peri-urbanen) Kleinstadt.


Diese Arbeit wurde durch das EU-RP7 Projekt PLEEC – "Planning for energy efficient cities" (EC-FP7, GA Nr. 314704) mitfinanziert. Artikel I und II bauen auf Material und Daten auf, die im Rahmen des Projektes gesammelt wurden.
Preface and acknowledgements

Addressing questions of sustainability, such as energy use in cities, demands navigating through a broad field of discussions, framed by an equally broad range of research approaches and concepts. At the same time, it requires positioning and focusing one's own study in a highly multi- and interdisciplinary field, while ensuring that relevant aspects among strongly interrelated lines of research are not neglected.

In this study, initially, I strived to incorporate all potentially relevant perspectives with respect to energy use in cities. However, I soon discovered that this was an unrealistic endeavour, although I still consider this initial ambition to be an important starting point for the research and discussion on sustainable development. I am convinced that sustainability can only be addressed by taking a holistic and interdisciplinary perspective, as complex problems require complex solutions.

Refining my approach within the sustainable development debate was one of the major challenges of this study and it dogged me throughout the entire process. Therefore, this thesis also represents my journey, which involved ‘digging’ through a considerable amount of literature and gradually developing my own perspective and research path.

Being given the opportunity to get to the bottom of a topic is possibly one of the most desirable tasks a curious mind could ask for. Questions of sustainability have always caught my interest, as a citizen and as an urban planner. Conducting this PhD study has been an exciting, adventurous, never boring, and sometimes exhausting, but certainly very privileged journey over the past three years. Reading everything that caught my interest and learning whatever was necessary to conduct my research, which ranged from improving my academic English to brushing up on statistics and learning the Danish language, has been an outstanding opportunity. Pursuing a PhD in Denmark entails much more than conducting one's research; it involves participating in courses, summer schools, and conferences, visiting other research institutions and engaging in project work, all of which have not only contributed to my work, but to my education and personal development, and I am very grateful for that.

Conducting this study would not have been possible without the support I received in various forms and from various people whom I would like to thank here.

First of all, I would like to express my deep gratitude to my supervisors, Trine Agervig Carstensen, Christian Fertner and Niels Boje Groth, who not only supported me in my transition from my previous working life to academia, but who also gave me freedom in research and guidance when needed. They encouraged me, shared their knowledge and spent innumerable hours engaging in my work. Without their guidance and personal support, this project would not have been possible.

I would also like to thank my other colleagues at the Section for Landscape Architecture and Planning for their academic advice and for always ensuring an inspiring and pleasant working environment; a
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I would like to thank my colleagues from the European project PLEEC – “Planning for Energy Efficient Cities”, in which I was involved especially in the beginning of my studies, which provided a perfect kick-off, inspiring discussions and a great ‘alternative’ working environment.

There are many people who accompanied me through these years, be it academically, personally, or both.

Mette, Christian, Iben and Frida welcomed me into their family from the moment I arrived in Copenhagen, always joyful and a great support at any stage, thank you so much!

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Ein ganz besonderer Dank richtet sich an meine Eltern für ihre bedingungslose Unterstützung, Zuwendung und Vertrauen, in jeglicher Hinsicht, und die mich nicht zuletzt zu einem neugierigen und kritischen Geist gemacht haben. Mein Bruder Fabian, der mein Leben mit Herz, Verstand und Humor einfach immer schon bereichert hat.

Last but certainly not least, muchas, muchas gracias, Mario, for your infinite patience, cheerfulness, unconditional support, constant assurance, and for sure the best tortilla de patatas.

However, I am solely responsible for any errors in this thesis.

Juliane Große
Copenhagen, June 2017
List of scientific papers

This PhD thesis has been carried out as a compilation of four scientific papers, which are consolidated in this synthesis. Paper I and II are already published in peer-reviewed journals. Paper III was recently submitted (May 2017), while paper IV was submitted in December 2016; both paper III and IV are in peer-review. All papers are included at the end of the thesis (see Paper I – IV).


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1 Introduction

1.1 Entering the discourse on energy use in cities

This PhD study explores the relationship between urban structure and travel behaviour in view of reducing transport energy use in urban areas. Cities are responsible for about two thirds of the world’s energy consumption and this share is expected to increase further due to high urbanisation rates (IEA, 2008; Madlener and Sunak, 2011). In the European Union (EU), 70% of the population live in urban areas with at least 5,000 inhabitants (European Commission, 2011a). In the Nordic region, 97% of the population growth during the past 20 years has taken place in 30 functional urban areas (Nordregio, 2016).

While cities account for the lion’s share of energy use and greenhouse gas emissions (Salat and Bourdic, 2011), they simultaneously play a key role in reducing resource consumption. This is also reflected in policy documents. For instance, for its ‘Smart, Green and Inclusive Growth’ initiatives of Europe 2020, the European Commission (2011a) considers cities to be key players. The United Nations’ (UN), too, attribute a special role to cities. Goal 11 (“Make cities inclusive, safe, resilient and sustainable”) of the UN sustainable development goals (SDGs) adopted in 2015 explicitly addresses the development of cities. Its specific targets include resource efficiency, mitigation and adaptation to climate change, reducing the adverse per capita environmental impact of cities as well as providing access to sustainable transport systems. Also other goals address issues with implied relevance for the sustainable development of cities (United Nations, 2015).

In 2008, the EU released the Climate and Energy Package 2020, which marks the cornerstone for achieving the EU’s so-called 20-20-20 targets\(^1\). Recent projections indicate that in order to achieve the energy consumption reduction target, additional efforts in the transport sector are also needed (EEA, 2016). The transport sector accounts for 33% of the final energy consumption (in 2015) and almost 25% of the greenhouse gas emissions (in 2014) in the EU (European Commission, Eurostat, 2016).

Energy efficiency is the “ratio of energy services out to energy input”, i.e. “getting the most out of every unit of energy you buy” (Herring, 2006). Thus, energy efficiency does not – in contrast to energy conservation – necessarily imply a reduction in energy consumption. The sustainable use of resources and the importance of actual energy savings, which implies absolute decoupling of economic growth from energy consumption, has been emphasised in many policy-related documents (e.g. EEA, 2015a; European Commission, 2011b, 2012; UNEP, 2013). Only absolute decoupling employs energy conservation, which cannot be achieved without structural changes, whereas relative decoupling simply means increasing energy efficiency (Jackson, 2009). Ironically, technological improvements that increase ener-

\(^1\) 20% reduction in greenhouse gas emissions (from 1990 levels), increase share of EU energy from renewable resources to 20% and 20% improvement in energy efficiency (reduce consumption).
Introduction

gy efficiency may even encourage increased consumption (Lyons, 2011; Vilhelmsen, 2007), also
known as the so-called ‘rebound effect’ (Sorrell et al., 2009). Though, efforts to reduce energy con-
sumption focus mainly on technology-based solutions.
Apart from industrial energy use, energy consumption in cities is mainly composed of energy use in
buildings (heating, cooling, electricity) and transport (Lewis et al., 2013). In the building sector, tech-
nological improvements (building technology, insulation, heating systems, etc.) already provide wide-
ranging solutions for reducing energy use. In transport, however, technological improvements fall
short of achieving the required reductions (Banister, 2011). Nonetheless, great effort is being put into
replacing conventional technologies with new ones, such as biofuels or electric vehicles (Bradshaw,
2014).
‘Technology fix’ is a more convenient choice as it suggests maintaining ‘business as usual’ (Lyons,
2011). However, reducing energy use for transport eventually demands a reduction in the volume of
environmentally harmful transport by initiating structural changes to adapt behaviour and travel pat-
terns (European Commission, 2012; Lyons, 2011), which is the subject of this PhD study.

1.2 Urban structure, travel behaviour and urban planning for sustainability

In the context of sustainable urban development, it is widely acknowledged that urban structure2 con-
tributes to achieving more sustainable travel patterns by reducing travel demands (distance) and
promoting the use of less energy-intensive transport modes, such as public transport, cycling, or walk-
ing, thereby reducing energy use for transport (Fertner and Große, 2016). As early as the late 1980s,
Newman and Kenworthy (1989) looked at a global sample of 32 cities and found that higher popula-
tion density, an attribute of urban structure, is correlated with lower fuel consumption (see Figure 1).
This opened the to date underexploited potential of urban planning agendas to stimulate changes to-
wards more sustainable transport patterns by shaping urban structure (e.g. Bulkeley and Castán Bro-
to, 2013).

2 ‘Urban form’, ‘spatial structure’ and ‘urban structure’ are sometimes used interchangeably in the scientific literature. The present study
uses ‘urban structure’ for addressing the overlap of urban form and spatial structure characteristics (see chapter 2.1.1).
European cities are much-quoted examples of sustainable and compact urban development in comparison to, for instance, US or Australian cities (Beatley, 2004; Girardet, 2004). One could argue that European cities benefit from more favourable preconditions as many were shaped before the automobile arrived and urban growth went along with developing public transport (Girardet, 2004, p. 143). However, as European showcases such as Copenhagen, Vienna and Zurich demonstrate, only comprehensive urban planning that adapts to ongoing dynamics and developments is capable of initiating the required structural adaptations. Changing travel behaviour, such as in the ‘cycling city’ Copenhagen, has resulted from the interplay of urban structure (compactness, mixed functions) and complementing measures (e.g., favouring public and non-motorised transport) through urban planning (Beatley, 2004; Girardet, 2004). Hence, urban planning has a high potential to affect the trends of urban development in a more sustainable way (Hagen, 2016).

Cities’ functioning (land use mix, patterns of spatial behaviour) and flows (travel, energy) are shaped by their urban structure (Salat and Bourdic, 2011). The role of urban structure in people’s travel behaviour marks the starting point of this study in order to evaluate the role of urban planning in stimulating more sustainable travel patterns by means of urban structure.
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1.3 Identifying research gaps and contribution of this study

The challenge of more sustainable transport as part of sustainable urban development has been the subject of research and planning practice for decades. Changing travel behaviour in the direction of more sustainable patterns in order to ultimately reduce transport energy use represents a crucial potential of urban planning, which so far has not been sufficiently exploited. The role of urban structure in travel behaviour is not yet comprehensively understood – also in relation to further determinants of travel behaviour. Understanding this relationship is considered a prerequisite for establishing implications for urban planning.

To date, research on travel behaviour has mainly focused on travel as a matter of routine (Vilhelmson, 2007), such as shorter daily travel related to work or leisure activities (Kristensen et al., 2014). Consequently, travel behaviour is predominantly assessed by criteria that apply to so-called bounded trips that are fixed in time and place. However, these criteria fall short when it comes to explaining non-bounded types of travel that are more flexible in time and place, such as non-routine leisure, weekend or holiday travel (see Næss, 2006a; Vilhelmson, 1999); see also section 2.3. This focus on bounded types of travel is also reflected in planning practice as non-bounded travel is not usually covered by urban planning agendas (Boussauw and Vanoutrive, 2017; Vilhelmson, 2007).

Consequently, particularly travel domains that are of a more non-bounded nature are still insufficiently understood in terms of the influence of urban structure, and also further determinants that influence travel behaviour, such as socio-economic factors or people’s attitudes and preferences (Holden and Norland, 2005; Holz-Rau et al., 2014; Reichert et al., 2016). This might lead to incomplete conclusions in terms of the role of urban structure, such as the widely accepted contrast between sustainable urban compared to unsustainable peri-urban travel patterns.

Travel domains that are to a greater or lesser extent non-bounded are characterised by varying attributes such as distance, purpose (e.g., tourism), destination (domestic/international) or mode (e.g., air travel). This illustrates the complexity of these travel domains, which makes it also difficult to estimate their extent. However, they already account for a considerable share of today’s transport volume and energy use and follow an upward trend, also due to their distance and the importance of other travel modes (e.g., plane) than those used in bounded trips.

In the more wealthy Western European countries, long-distance travel (≥100 km) is estimated to account for almost 50% of the greenhouse gas (GHG) emissions from travel (van Goeverden et al., 2016). Tourism-related trips are expected to increase exponentially regarding frequency and distance, especially air travel (Gössling et al., 2013, 2010), which reached 640 million arrivals by plane in 2015 (World Tourism Organization, 2016). Also in Denmark, international travel, especially air travel, has increased rapidly, and it accounted for 31% of CO₂-emissions from travel in 2010 (Christensen, 2016; Knudsen, 2014). In Sweden, about half of all domestic travel is related to leisure (Vilhelmson, 2007).

In light of the outlined research gap, the study aims to contribute to a more comprehensive understanding of travel behaviour, particularly with respect to the role of urban structure in travel of bounded...
ed in comparison to travel of non-bounded nature, which is of substantial relevance for urban planning. For this purpose, the study applies an integrated analysis across different travel domains (daily work and leisure, weekend trips, holidays) and, besides urban structure, it accounts for further parameters, such as socio-economic and socio-demographic factors, and people’s attitudes and preferences, in order to isolate the effect of urban structure and, subsequently, derive implications for urban planning.

1.4 Objectives and research questions

The aim of this research is to understand the relationship between urban structure and travel behaviour in order to evaluate practices and the capacity of urban planning to change travel behaviour in the direction of more sustainable patterns. Travel behaviour is considered a purposeful proxy representing the structural aspects of transport energy use that are reflected in energy-intensive travel patterns (car or plane use).

The study pursues three objectives: Firstly, the study aims to conceptualise the scope (fields of action) and key framing conditions (potential and constraints) for urban planning, especially regarding transport planning. Secondly, the study aims to explore the role of urban structure of people’s living environment and further explanatory factors in their travel behaviour in terms of daily travel (conceptualised as ‘modality styles’) and weekend/holiday travel. Thirdly, the study aims to develop implications for urban planning and related recommendations for changing travel behaviour.

In response to the stated objectives, the study is guided by the following three main research questions:

1. What role can urban planning play in increasing energy efficiency, particularly in transport, by working with urban structure? (paper I and II)

2. How does daily travel behaviour (‘modality styles’) correspond with weekend/holiday travel behaviour and what is the role of urban structure and potential further factors in constituting travel behaviour? (paper III)

3. Are there any differences in weekend and holiday travel between people who reside in urban versus peri-urban areas that can be qualified as ‘compensatory travel’, i.e. triggered by the urban structure of the living environment? (paper IV)

The study aspires to make a twofold, strongly empirically established contribution to the field, which corresponds to its disciplinary anchoring in urban planning: (1) To fulfil an analytical goal, which could be understood as theory building with regards to understanding travel behaviour in support of a societal goal (reducing energy consumption), and; (2) to fulfil a practical goal regarding developing implications for urban planning for changing travel behaviour through urban structure (Farthing, 2016; Götz and Ohnmacht, 2011).
1.5 Structure of the thesis

This PhD study is a compilation of four scientific papers (see Paper I – IV included at the end) and this synthesis. Each paper focuses on one of the research questions and feeds into the stated objectives (see Figure 2):

- Paper I and II elaborate on the scope and key framing conditions for urban planning (objective 1); paper I is based on a literature review, while paper II combines a literature review with an empirical study.
- Paper III and IV elaborate on the role of the urban structure of people’s living environment in their travel behaviour by applying an empirical approach (objective 2).
- All papers contribute to the third objective of developing implications for urban planning, which is further developed in this synthesis.

Paper I and II take a more explorative perspective, whereas paper III and IV each investigate a very specific research question which is guided by theoretical assumptions.

![Diagram of objectives and papers](image)

**Figure 2:** Structure of the thesis and contribution to the objectives

The development of the papers and research questions was preceded by an extensive literature review on the concept of urban structure and the state of research regarding the relationship between urban structure, transport energy use, and travel behaviour. A summary of this literature review is taken as the starting point for the background and framing of this thesis and is included in section 2.1. The second and third research question were developed and specified by extending the research background with further conceptual work for understanding and explaining travel behaviour (section 2.2) and linking it with the concept of urban structure (section 2.3). The findings of paper I and II regarding the role of urban planning already provide a relevant intermediate result for the following papers, which is, therefore, introduced as part of the research background (section 2.4). In chapter 3, research design and applied methods are summarised and the studied cases are introduced. Chapter 4 provides a brief introduction to the four papers, the results of which are discussed in chapter 5, which also addresses the limitations of the study. The thesis rounds off with the overall conclusions that summarise the outcomes of the papers and some perspectives for future research (chapter 6).
2 Research background of the study

The starting point of this study is the exploration of the potential of urban structure to reduce transport energy use in cities. Travel behaviour is employed as a proxy for transport energy use, reflecting the social practice dimension of travel, such as car or plane use. Hence, this study investigates how urban structure affects travel behaviour, and how urban planning can engage in this relation. These central concepts and how they are understood, linked and utilised for the purpose of this study are outlined in this chapter together with an overview of the state-of-the-art of research. Therefore, research gaps are also further outlined.

Firstly, this chapter elaborates on the concept of urban structure with regards to transport energy use and travel behaviour (section 2.1). Secondly, further determinants that influence travel behaviour beyond urban structure, e.g., socio-economic factors, are explored and conceptually framed by contributions from travel behaviour research (section 2.2), which are, finally, linked with the concept of urban structure to form the research background of this study (section 2.3). Section 2.4 complements the research background by outlining the role of urban planning with regards to addressing travel behaviour by dealing with urban structure.

2.1 The relationship between urban structure and transport

This section introduces the concept of urban structure with regards to transport energy use in cities and summarises the state of research regarding the influence of urban structure on transport energy use and travel behaviour.

2.1.1 The concept of urban structure

The potential of urban structure to influence energy use in cities has been the subject of planning research and practice for more than three decades. This has come along with the establishment of urban development concepts that are guided by energy efficiency-principles.

A comprehensive examination of how spatial structure determines energy demand and consumption (e.g., transport and district heating) was conducted by Susan Owens (1986). Although mostly referring to ‘spatial structure’ as land use, the introduced set of ‘structural variables’, besides settlement pattern, size and shape, density, mix of land uses, degree of centralisation of facilities and layout, also includes parameters at the building level and communication networks (Owens, 1986). Energy efficient spatial structure is accordingly characterised by compactness, mix of land uses, clustering of trip ends and, to some degree, self-contained urban units (Owens, 1986).

Based on these characteristics, three basic types of energy efficient spatial structures are outlined: The ‘compact city’ achieves “high densities and integration of activities” by “containing the functions of a large city within a small area of land” (Owens, 1986, p. 62). ‘Decentralised concentration’ (polycentric spatial structure) is characterised by “compact nucleated urban subunits having ‘walking distance’ or
bicycle scales” (Owens, 1986, p. 63). The ideal size of these sub-areas is determined by travel requirements and the need to provide everyday facilities. Thirdly, ‘linear grid structure’ is characterised by “high linear density of development” and the integration of land uses by ”concentrating origins and destinations of trips onto a small number of routes” (Owens, 1986, p. 65); it is also considered to be an ideal structure for public transport.

These basic types of urban structure can be opposed to non-energy efficient structures, characterised by ‘decentralisation’, which refer “to all forms of population and industrial growth taking place away from existing urban centres” (Breheny, 1995, p. 87), such as ‘urban sprawl’ (EEA, 2006).

The scientific literature does not provide a consistent application of the terms ‘spatial structure’, ‘urban form’, ‘urban structure’ and sometimes ‘land use’. Therefore, they are occasionally used interchangeably. In the present study, urban form is understood as, e.g., morphology, layout, built environment and density; whereas spatial structure refers to, e.g., land use, mix of functions or uses and proximity/accessibility. Consequently, urban structure, which is the subject of this study, is understood as and used for describing the overlap of urban form and spatial structure, i.e. the combination of characteristics of both dimensions.

This combination of urban form and spatial structure characteristics is illustrated by urban development concepts such as the compact city or transit-oriented development.

The compact city has, in line with Owens’ (1986) definition, an urban form dimension in terms of ‘density/compactness’ and a spatial structure dimension in terms of ‘intensity’ as a measure of urbanity related to the use of space (Westerink et al., 2013). Hence, ‘intensification’ refers to the built form and urban activity (Williams et al., 1996); aiming at “using urban land more efficiently and intensifying development and activity” (Jenks, 2004, p. 242).

Transit-oriented development has evolved in North America as a neo-traditional response to the compact city and is an integrated spatial and transport planning concept, although it is mainly applied in new or suburban development areas (Handy, 1992; Mindali et al., 2004). It combines “moderate and high density housing” with mixed uses such as commercial, employment and service provision concentrated along the regional public transport system (Calthorpe, 1993, p. 41).

Both examples illustrate that density and compactness (urban form) do not necessarily imply proximity/accessibility (spatial structure). If urban functions are split into functionally distinct urban districts (zoning), other structural parameters, e.g., the connection between urban functions and the transport system (accessibility), become essential. Accessibility can be conceptualised by spatial dimensions distinguishing “locational accessibility; i.e., proximity” and “distance-bridging accessibility; i.e., mobility” (Haugen, 2012, p. 4).

Proximity and accessibility are essential to the concept of urban structure, implying that urban structure is intrinsically linked to questions of transport and travel behaviour. The compact city, for instance, loses its major advantage when the distance between its core and its fringe becomes too far (Owens, 1986; Westerink et al., 2013). This leads to a “polycentric interpretation of the compact city”
where *proximity* is gradually displaced by the idea of *accessibility* (Westerink et al., 2013, p. 476) and where the importance of public transport as a complement to the compact city is emphasised (see Rickaby and Steadman, 1991).

Hence, there is no clear distinction, but rather a continuum between different types of urban structure; even more because urban structure is shaped by the embeddedness of a city in its functional urban area (Antikainen, 2005) and the position in the regional urban system.

**2.1.2 Urban structure and transport energy use**

The impact of different types of urban structure on transport energy use has been largely established by estimating fuel consumption due to car use in cities or by comparing the share of different transport modes (e.g., car use vs. public transport use).

Among the first and often-quoted contributions that has assessed the relationship between urban structure and transport energy use is the study of the Australian researchers Newman and Kenworthy (1989), who found a negative relationship between fuel consumption and population density for a global sample of cities (see Figure 1). They concluded that locational factors have a greater impact on fuel consumption than congestion; hence, compact urban structure is considered the preferable strategy for energy conservation (Newman and Kenworthy, 1988).

Their arguments for compact urban structure (e.g., energy conservation) have been contested (Gordon and Richardson, 1997, 1989), while other analyses of the same data have arrived at different results (e.g. Mindali et al., 2004). Mindali et al. (2004) used different methods and obtained ambiguous results regarding the relationship between urban density and energy use for transport: Firstly, the sampled cities are divided into two main clusters – European and US/Australian cities. Secondly, for the US/Australian cluster, no effect of density on transport energy use has been identified, while for the European cluster, only a limited influence of land use on transport energy use is confirmed. The study highlights, however, the importance of public transport (Mindali et al., 2004).

In contrast, a later study estimates for the US possible reductions in vehicle-miles travelled (VMT) per capita with 20-40% through compact development compared to sprawl, depending on the specific characteristics of urban structure (Ewing et al., 2008). A study from Japan confirms a relationship between urban structure and car use (fuel consumption) by comparing historical cities and cities rebuilt after World War II. The latter show higher fuel consumption, which the authors attribute to the beginning of the ‘automotive era’ that has been implemented in the urban structure (Taniguchi and Ikeda, 2005).

As illustrated by the empirical examples above, the size of the effect of urban structure for transport energy use depends on the context besides the underlying specifications and assumptions of the analyses. However, it is evident that urban structure influences energy use for transport. This has been further developed by a branch of research that relates the influence of urban structure directly to travel patterns (i.e. human activity patterns) and derives implications for facilitating certain travel behav-
Research background of the study

...such as replacing car use by public transport, cycling or walking, through specific characteristics of urban structure.

2.1.3 Urban structure and travel behaviour

Central findings on the relationship between urban structure and travel behaviour have emerged from several studies on Nordic cities and towns: Travel patterns are significantly influenced by distance/time, accessibility, comfort of use (flexibility), price, and opportunities to combine different modes of transport (Næss, 2006a). Accordingly, travel is understood as a trade-off between attractiveness of the destination (reasons for going to a place) and friction of distance (discomfort induced through travelling) (Næss and Jensen, 2004). Hence, urban structure has the potential to influence people’s travel behaviour (Næss, 2006a) because “urban structure makes up a set of incentives facilitating some kinds of travel behaviour and discouraging other types of travel behaviour” (Næss and Jensen, 2004, p. 37). In summary, city size, density and concentration, mixed land uses (diversity), accessibility and concepts of self-containment are identified as key features for reducing travel distances and travel by car in favour of higher shares of public transport, cycling and walking (Banister et al., 1997; Cooper et al., 2001b, 2001a; Limtanakool et al., 2006; Næss et al., 1996; Næss, 2006a; Schwanen et al., 2004). These key features of urban structure were also summarised as the so-called ‘3 D’s’ – density, diversity and design (Cervero and Kockelman, 1997), which were subsequently extended to the ‘5 D’s’ through the inclusion of destination accessibility and distance to transit (Ewing and Cervero, 2010).

The findings with regards to relevant parameters of urban structure have been confirmed and further developed, specifically with regards to the importance of scale and the regional urban system. For instance, compact cities may vary in size (e.g. Boussauw et al., 2012), while polycentric structures may be local (neighbourhood) or up to regional (urban systems) consisting of several compact cities. This stresses the need for context-dependent assessments of the effect of urban structure.

A review of studies from the Nordic countries concludes that at a wider regional scale decentralised concentration may be the most energy-efficient spatial structure (Næss, 2012, p. 41). Polycentric urban regions are considered to favour shorter commuting distances (Grunfelder et al., 2015). In contrast, findings from the Netherlands show higher levels of commuting by car in polycentric spatial settings compared to monocentric ones (Schwanen et al., 2003, 2001). However, the specific characteristics of urban structure in the Dutch context, such as close proximity between the urban areas, highlight the importance of distinguishing between different types of polycentric urban systems (Schwanen et al., 2003).

With regards to travel behaviour, the different findings illustrate that a conceptual comparison, whether the compact city or polycentric structures are favourable, is not useful. Types of urban structure should rather be assessed along the continuum between the compact city and polycentricity, which translates into different characteristics with regards to proximity and accessibility as illustrated...
by the relevance of scale and context (e.g. Boussauw et al., 2012; Boussauw and Witlox, 2011). The complex dichotomy between proximity and accessibility is exemplified by two Swedish studies, which found that people tend to utilise local service amenities, although they were also willing to travel regionally (>50 km) when a large supply of amenities was accessible (Haugen and Vilhelmsen, 2013). Hence, people do not necessarily make use of shorter distances for reducing their travel (Haugen et al., 2012), but instead trade the attractiveness of the destination off against the friction of distance.

2.2 Beyond urban structure: Towards a comprehensive understanding of travel behaviour

2.2.1 Determinants of travel behaviour beyond urban structure

So far, it has been argued that compact and concentrated urban structures facilitate and favour the efficient use of transport energy in cities, although it seems difficult to clearly verify the relationship between urban structure and travel behaviour (e.g. Næss, 2006a; Pinho and Silva, 2015; Wee and Handy, 2016). However, travel behaviour cannot be sufficiently be explained by urban structure (e.g. Crane, 2000; Lin et al., 2015). A review of empirical studies that address the relationship between urban structure and travel behaviour from the previous 20 years has identified two major shortcomings: establishing causality of relationships, and accounting for socio-economic factors, which are considered to affect travel patterns (Stead and Marshall, 2001).

Many studies that confirm the link between urban structure and transport energy use point at the same time to the relevance of socio-economic factors as well as attitudes, consumer choice and lifestyle (Banister et al., 1997; Cooper et al., 2001b, 2001a; Ewing and Cervero, 2001; Næss, 2012). Particularly socio-economic and employment profiles, car ownership and income are considered to have an influence on travel patterns (Silva et al., 2015; Stead et al., 2004). Further studies highlight the importance of personal attributes (Dieleman et al., 2002; Schwanen et al., 2001; van Acker et al., 2007); in particular people's characteristics and their position in the household (Schwanen et al., 2003). Meurs and Haaijer (2001) argue that the effect of urban structure is greatest for shopping, whereas commuting is mainly explained by personal characteristics; however, they refer to the number of trips, which are – with regards to commuting – probably mainly linked to employment, but not urban structure (see Elldér, 2014a).

The stepwise recognition of additional determinants besides urban structure is apparent in the latest expansion of the '5 D's', which became the '7 D's' with the inclusion of demand management and demographics (Ewing and Cervero, 2010). A recent review (Lin et al., 2015) suggests further extending the socio-economic factors, claiming that besides urban structure not only socio-economic factors at the individual level but also at the city level influence travel behaviour, such as urban historical and cultural factors, institutional and economic factors, which are related to the notion of mobility cultures (see section 2.2.3).
Research background of the study

In conclusion, the relationship between urban structure and travel behaviour has been comprehensively researched, although the focus has been largely on *bounded trips*. The influence of urban structure as well as other factors, such as socio-economic factors or attitudes, is not uncontested and concepts for explaining the relationship between urban structure and travel behaviour are under continuous refinement and extension. Yet, urban structure remains a necessary precondition (Naess, 2006a) that defines the “exogenous baseline conditions provided for travel choice” (Silva et al., 2015, p. 24) at least with regards to *bounded* trips. However, according to the above summarised studies, the outlined additional determinants (socio-economic and socio-demographic factors, attitudes or lifestyle-related factors) beyond urban structure appear to be essential for explaining travel behaviour, possibly even more so for *non-bounded* trips.

### 2.2.2 Explaining travel behaviour

Understanding and explaining travel behaviour has been the subject of different research disciplines which have provided distinct conceptual frameworks that have only recently been employed more linked with each other. *Transport geography*, which accounts for the spatiotemporal and socio-economic component, on the one hand, and *social psychology*, which accounts for the personality component, on the other hand, comprise two central disciplines (van Acker et al., 2010).

A basic concept of transport geography was introduced by Hägerstrand (1970) as the ‘time-space-concept’, according to which individuals’ activity patterns are determined by *constraints*3, such as workplace presence, access to transport systems, or residential location, which enable and constrain an individual to move within a certain *time* and a certain *space* (distance). The ‘activity-based approach’ has adopted the time-space-concept and added the notion that human activity patterns are driven by *needs* and *choices* (see Eldér, 2015; Shiftan, 2014). Accordingly, in modern society high-speed travel has led to extended ‘activity spaces’ and dependency on high levels of mobility such as car use (Vilhelmsen, 2007). A commonly used theory in social psychology is the theory of planned behaviour (TPB) (e.g. Anable, 2005; Haustein and Hunecke, 2007).

The conceptual frameworks of *transport geography* and *social psychology*, which account for the spatiotemporal, the socio-economic and the personality component, have been complemented by the introduction of a *lifestyle component*, which allows the interrelations between transport geography and social psychology to be captured (see Krueger et al., 2016; van Acker et al., 2010).

The present study is anchored in the understandings of transport geography. *Urban structure* is understood as constituting constraints that facilitate certain travel behaviour. Given the limitations of urban structure for explaining travel behaviour, the study borrows additional concepts from travel behaviour research, such as the concept of *modality styles*, which facilitates to account for further determinants in order to finally qualify the role of urban structure.

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3 Hägerstrand (1970) conceptualised three kinds of constraints: *capability constraints*, *coupling constraints*, and *authority constraints*.
2.2.3 Lifestyle, travel behaviour and modality styles

*Travel behaviour and lifestyle*

As outlined above, besides its spatiotemporal dimension, travel behaviour has a social dimension. Travel patterns can be considered as *social practice*. In our contemporary world, this is expressed in high-carbon living that has become *habitual* (Urry, 2011), such as car use and increased use of the plane. The concept of *habitus* has been introduced by Bourdieu (1984) and contributes to understanding lifestyle as a latent structure. *Habitus* forms "a system of dispositions" (Bourdieu, 2002, p. 27) upon which lifestyles are based. Thus, *habitus* acts as a “mediating link” between objective and subjective *structures* and *practice* (Aner, 2016, p. 4).

Lifestyles are rooted in *habitus*, and *habitus* determines behaviour (*practice*) (Richter, 1994, p. 356), such as travel behaviour. Hence, patterns of travel behaviour can be understood as lifestyle expressions (van Acker et al., 2016).

*Individual* travel behaviour has also been framed as an element in an 'extended choice hierarchy'; travel behaviour is considered a *short-term decision* that fulfils *long-term lifestyle* decisions. A further element in the 'extended choice hierarchy' is the *mid-term decision for a residential location* (Salomon and Ben-Akiva, 1983). Accordingly, lifestyle has a *behavioural* and a *residential* representation.

Lifestyle is expressed in residential choices (Ærø, 2006; Scheiner and Holz-Rau, 2007); hence, different travel patterns related to different residential locations might originate in the underlying lifestyles of the people who live there. In an ideal-typical understanding, certain lifestyles are situated predominantly in certain spaces (e.g. Dangschat, 1994; Richter, 1994). Urban dwellers are commonly considered to be more outward-oriented and active, whereas small town or rural dwellers are characterised as being predominantly preserving and more traditional (Richter, 1994); but at the same time avoiding to impose a strict dichotomy between 'urban' and 'rural lifestyles'. For instance, in the Danish context, the increasing number of young families who are moving from the city to the countryside (Aner, 2016) might lead to an increasing heterogeneity of ‘rural lifestyles’.

Thus, travel behaviour research needs to account for lifestyles (e.g. Scheiner and Holz-Rau, 2007; van Acker and Witlox, 2009; Vij et al., 2013). The previously outlined additional determinants besides urban structure, such as socio-economic and socio-demographic factors, preferences and (travel-related) attitudes, are linked to the notion of lifestyle (see van Acker and Witlox, 2009), which is expressed in residential choices and travel behaviour. Acknowledging *lifestyle* as a meta-concept helps to fill the explanatory gaps when attempting to understand travel behaviour with regards to urban structure.
Research background of the study

Mobility and modality styles

A concept that has emerged for integrating the lifestyle component in travel behaviour research is the concept of modality styles (Krueger et al., 2016). Modality styles are embedded in the broader notion of mobility styles (see Figure 3), i.e. understood as an expression of the latter (Olafsson et al., 2016; Vij et al., 2013). Corresponding to the notion of habitus, modality styles are “behavioral predispositions, characterized by a certain travel mode or set of travel modes that an individual habitually uses” (Vij et al., 2013, p. 165).

Associated with certain residential locations, modality styles are situated lifestyle representations, stressing the link between the spatial (residential location) and the behavioural (travel behaviour) component through lifestyle (see Klinger and Lanzendorf, 2016).

The concept of mobility styles has emerged for dividing a population into homogenous groups with similar attributes that are considered relevant for explaining travel behaviour (Barr and Prillwitz, 2012). Analytically, it originates from the idea of market segmentation or customer classification (Di- ana and Mokhtarian, 2009). Existing studies deploy different strategies for grouping individuals depending on the travel behaviour-related attributes that are being investigated; commonly used are socio-economic factors (e.g. Ryley, 2006), attitudes (e.g. Anable, 2005; Barr and Prillwitz, 2012; Ohnmacht et al., 2009; Prillwitz and Barr, 2011), actual travel behaviour (e.g. Olafsson et al., 2016; Prillwitz and Barr, 2011), or a combination of the aforementioned (e.g. Lanzendorf, 2002). Existing studies show that lifestyles are a relevant latent determinant in leisure travel (e.g. Böhl er et al., 2006; Lanzendorf, 2002; Ohnmacht et al., 2009). However, only a limited number of mobility styles studies has included different types of leisure travel, either solely (e.g. Lanzendorf, 2002; Ohnmacht et al., 2009) or by combining different travel domains (e.g. Prillwitz and Barr, 2011).

For its empirical application (paper III), the present study refers to modality styles, applying grouping based on daily mode choices (work and leisure) and including two distinct residential locations. By relating those modality styles to weekend and holiday travel behaviour, socio-economic and socio-demographic parameters as well as travel-related attitudes, the study seeks a more comprehensive understanding of travel behaviour in order to qualify the role of urban structure in the different travel domains.

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* Mobility styles are contextualised in the concept of mobility cultures; mobility cultures comprise, besides the actor-oriented mobility styles, the spatial, social and political elements and dynamics of mobility, such as transport planning, mobility-related discourses, and the historically developed urban space (Dief ner et al., 2006; Klinger et al., 2013).
2.3 The interplay between urban structure, travel behaviour and further determinants

So far, the study has introduced the concept of urban structure in relation to transport energy use and travel behaviour (section 2.1), and extended the framework to include additional determinants of travel behaviour (section 2.2). This section summarises how these two conceptual framings are linked together to form the research background of this study, particularly with regards to paper III (“Modality styles in Greater Copenhagen”) and paper IV (“Compensating for Compactness”).

Limitations of the concept of urban structure

Urban structure alone cannot constitute, but is necessary to facilitate sustainable travel behaviour. The concept of urban structure falls short of accounting for socio-economic and socio-demographic factors, people’s preferences, attitudes and lifestyles. The intrinsic link between travel behaviour and these additional factors becomes evident with regards to residential choices. People’s residential choices are determined by their socio-economic capabilities (e.g. income), but also their lifestyle-related preferences, such as space for children, or travel-related preferences, which is conceptualised as residential self-selection. Self-selection assumes that people choose their residential location based on their attitudes and preferences (van Acker et al., 2010), particularly based on those related to travel (Bohte et al., 2009; de Vos and Witlox, 2016; van Wee, 2009).

A further limitation of urban structure concerns its influence on bounded compared to non-bounded trips (see Näss, 2006a). Corresponding to the ‘time-space-concept’, activity-related trips are situated along the continuum between fixed (bounded) and flexible (non-bounded) along the two dimensions ‘time’ and ‘place’ (Vilhelmsen, 1999). Work or education related trips are, to a high degree fixed, in time and place, whereas trips related to regular leisure activities may, to a certain extent, be fixed in time (after work, weekend), but less so in place, while trips related to non-routine activities, such as weekend trips or holidays, are even less fixed, in time and place. The potential of urban structure to affect one type or the other more effectively is assumed to vary correspondingly. Näss (2006a) argues that bounded trips are more likely to be influenced by urban structure than non-bounded trips. This has also been confirmed by a Swedish study (Elldér, 2014a), which found daily distance travelled to work and service errands, i.e. bounded trips, were largely explained by residential location, but this was not the case for leisure trips and weekend travelling (without overnight stays); although the effect of residential location appears to have decreased over time (Elldér, 2014b).

As yet, few studies have (indirectly) addressed the role of urban structure in non-bounded travel by comparing different spatial settings. It appears that, in general, urban dwellers undertake more distant and more frequently long-distance trips (e.g. Frändberg and Vilhelmsen, 2003; Holz-Rau et al., 2014; Reichert et al., 2016). However, the extent to which this is linked to urban structure itself (e.g., through ‘compensation’, see below) or is rooted in lifestyles that are dominant in certain urban structure settings (residential locations) remains to be determined.
Research background of the study

Challenging the compact city – Trade-offs and compensatory activities?

Compact city development has never been an undisputed planning paradigm. The compact city is the result of “sustainability trade-offs” (Westerink et al., 2013, p. 477), a balance between positive and negative features of high density (Hall, 1997). The main trade-offs of dense and compact urban structure originate in the disadvantages of density: Limited access to green spaces for outdoor leisure activities and recreation (Breheny, 1992; Owens, 1986), higher levels of air pollution (Schindler and Caruso, 2014) or the urban heat island effect (UHI) (Madlener and Sunak, 2011).

With regards to travel behaviour, a phenomenon which features in the discourse on trade-offs is ‘compensatory travel’. Put simply, the underlying hypothesis is that dense and compact living may stimulate increased leisure travel in order to compensate for the disadvantages of density. This phenomenon has also been referred to as the ‘compensation hypothesis’ or the ‘escape hypothesis’ (Holden, 2007; Holden and Norland, 2005; Næss, 2016, 2006b).

Compensatory travel is discussed in the context of rebound effects, although the demarcation of the terms may be difficult to determine (see Næss, 2016). Rebound effects represent, as previously discussed, some sort of extra or new energy consumption as a consequence of increased efficiency. Thus, rebound effects and compensatory travel are also related to lifestyles. Rebound effects are divided into direct, indirect or economy-wide effects (EEA, 2013). In an urban context, rebound effects can be understood as, e.g., the additional consumption of goods and services, i.e. indirect rebound (Heinonen et al., 2013, 2011; Heinonen and Junnila, 2011; Poom and Ahas, 2016), or, e.g., increased leisure travel, i.e. direct rebound in the form of compensatory travel.

Both are considered a consequence of time and/or money surplus due to efficiency savings. Assuming that people dedicate a more or less stable budget of money and time to travel, savings in daily travel may enable compensation (Holden and Linnerud, 2011; Næss, 2006b; Vilhelmson, 2007; Zahavi, 1974).

Considering rebound effects is relevant for policy-making as studies reveal that policies that aim to increase energy efficiency may cause rebound effects or compensation (e.g. Chitnis et al, 2014; Holden and Linnerud, 2011).

Against the background of the core topic of the present study, which is to investigate the role of urban structure in travel behaviour, this study analyses ‘compensatory leisure travel’ as response to the negative features of dense and compact urban structure (paper IV), but it does not address a wider set of – indirect – rebound effects.

Travel as demand vs. travel for its own sake

The interplay between urban structure and lifestyle to explain travel behaviour is further demonstrated by the distinction of travel as demand or necessity (getting to work/education, dropping off and collecting children, shopping, etc.) compared to travel that is not derived from demand, but is engaged in for its own sake (e.g., cruising, recreational cycling) also termed as ‘undirected travel’, ‘excess travel’
(Cao et al., 2009; Handy et al., 2005; Mokhtarian and Salomon, 2001), or travel as a *valued activity* in itself (Banister, 2008), i.e. travel undertaken by *choice* (Holden and Linnerud, 2011).

Determining whether travel is the result of demand or is engaged in for its own sake, may often not be very clear and is, to some extent, subjective. For instance, whether weekend and holiday travel is derived from a demand (for, e.g., relaxation, recreation, family obligations) or is engaged in for its own sake is debatable. There are many different reasons and motivations for leisure travel (Mokhtarian et al., 2015) and, therefore, the extent to which they are the result of demand differs.

Even though the distinction might not be very accurate, it provides some sort of conceptual category that highlights the lifestyle component that has to be included in explanations of travel behaviour, also with regards to bounded or non-bounded trips, or compensatory travel. Urban structure, socio-economic factors, attitudes, preferences and lifestyle have to be addressed in an integrated manner to identify motivations and, hence, explanations for travel.

*Linking the concepts: Urban structure and further determinants of travel behaviour*

Urban structure, residential location, lifestyle and related attributes, and travel behaviour are strongly interrelated, which makes separating the effect of urban structure from other factors challenging. Explaining travel behaviour requires the inclusion of objective (e.g., urban structure) and subjective parameters (e.g., residential choices, car availability, travel-related attitudes, lifestyle) and their interrelations (van Acker et al., 2011).

Figure 4 represents an attempt to link the identified relevant concepts in a common framework to explain travel behaviour by simultaneously accounting for urban structure (residential location) and lifestyle, including its related attributes, as well as the links between these factors. The links in Figure 4 show that an influence exists, but do not indicate the extent of that influence. This study elaborates on the highlighted links in order to examine the effect of urban structure and, subsequently, determine the implications for urban planning.
2.4 The role of urban planning with respect to urban structure

The final objective of this PhD study is to go beyond achieving an understanding of the role of urban structure in travel behaviour and determine implications for urban planning. Therefore, conceptualising the scope and key framing conditions of urban planning with regards to transport planning formed the initial objective of the study. This section summarises the relevant findings from the literature as well as the results from paper I and II, which complete the research background.

Optimising and complementing urban structure

Dealing with urban structure can be considered as the inherent preserve of urban planning. However, planning decisions are accommodated slowly, and have far-reaching, long-lasting or partly irreversible consequences. Moreover, substantial changes in urban structure are hard to implement as urban planning mostly has to deal with existing urban structure, while new urban areas are only developed from scratch occasionally (e.g. Anderson et al., 1996; Williams et al., 2004). Accordingly, Girardet (2004, p. 151) detects a major change in urban planning with a “new emphasis on remodelling and regenerating existing cities and subtly re-integrating the diverse functions of urban life, reconnecting living and working in newly pedestrianised inner city areas wherever possible”.

The OECD definition of a compact city comprises key characteristics in terms of urban structure that cover aspects of land use, density, or mix of functions, but also complementing measures, such as public transport systems (OECD, 2012). This approach is supported by the earlier findings of Rickaby and Steadman (1991) who show that, for different types of compact cities, significant reductions in
transport energy use can only be induced by competitive public transport systems and accompanying policies. Further, research that advocates the influence of urban structure, also advocates the importance of accompanying policies to reduce car-based transport, such as fuel taxes (Breheny, 1995), reducing inner-city parking space and narrowing roads in city centres (Næss, 2006a), or introducing parking regulations and road pricing (Banister, 2008; Kristensen et al., 2014). All these findings emphasise the underlying notion of the interdependency between urban structure and transport, especially with regards to public transport (Anderson et al., 1996; Cooper et al., 2001a, 2001b; Rickwood et al., 2008), which is intrinsically linked to the feature of accessibility. Achieving benefits through urban structure is ultimately tied to transport planning.

Hence, the potential of urban planning to fundamentally change (re-build) urban structure is possibly limited, but it encompasses a range of opportunities for modifying and optimising urban structure by ‘complementing’ or ‘accompanying’ measures and policies, such as those related to transport planning.

**Scope of urban planning**

Planning for sustainability is not covered by a comprehensive responsibility. Actions towards sustainability rather rely on deliberate efforts as well as partnerships and cooperation by and between, e.g., local and regional authorities, citizens, enterprises, key stakeholders, private actors and public utilities (e.g. Banister, 2008; Nordregio, 2016). Furthermore, functional relations such as transport usually exceed administrative boundaries. Hence, policy-making that is primarily determined by administrative boundaries and government levels is insufficient or may even be counterproductive (Lundqvist, 2015; Marsden and Rye, 2010) as a city cannot be disconnected from its functional urban area.

This represents a dilemma for urban planning; on the one hand, urban planning is considered well placed and suitable for influencing changes in urban structure (Næss, 2006a) as well as “co-ordinate the variety of factors which individually and collectively are able to influence more sustainable travel patterns” (Stead and Marshall, 2001, p. 136). However, on the other hand, gaps in coordination at the regional or local level, or among constituent municipalities can lead to segmented policy-making, inefficiencies and organisational problems, e.g., in public transport provision (Geerlings and Stead, 2003).

Planning in the Nordic countries is characterised by a rather weak regional level, which means that planning tasks that cross municipal borders are challenging. Although municipal cooperation is a growing phenomenon, it still relies on voluntary cooperation (Jørgensen and AErø, 2007). Moreover, local planning takes place within policy regulations from higher tiers of government, which determine the range of local options (van Stigt et al., 2013).
Research background of the study

**Urban planning within three dimensions**

As previously mentioned, this section introduces some of the results derived from paper I and II as they concern aspects that are relevant to the research background. The objective was to conceptualise the scope and key framing conditions for urban planning, especially regarding transport planning, in order to determine the role urban planning can play by working with urban structure. The empirical research confirmed the results of the literature review: dealing with urban structure requires complementing policies and regional cooperation, which frames the role of planning: Urban planning acts with and within the three interrelated dimensions *urban form/spatial structure, policy context and functional relations* (see Figure 5).

![Diagram showing urban planning framework](image)

**Figure 5:** The role of urban planning as framed by urban form/spatial structure, functional relations and policy context as interrelated dimensions (Große et al., 2016)

*Functional relations* refer to interactions that occur in the urban area and beyond, such as transport and energy flows, and the city’s position in the regional urban system. The *policy context* refers to organising principles such as the planning system and higher-tier policies.

These dimensions frame the potential of and constraints on urban planning with regards to shaping (designating urban functions, density of the built environment) and optimising (connections between urban functions) the urban structure.

Relating this framework to the previously outlined considerations on travel behaviour and limitations of urban structure anticipates limitations of *urban planning*: When it comes to non-bounded travel, factors other than urban structure (e.g., socio-economic factors, lifestyle) can be expected to be important. This potential urban planning dilemma is addressed in an integrated discussion of the results (see chapter 5).
3 Research design and methods

3.1 Science-philosophical worldview with respect to planning research

The present study is informed by a critical realist worldview, which is reflected in the study design and the applied methods (see Creswell, 2009). Critical realism has emerged out of the “positivist/constructivist ‘paradigm wars’ of the 1980s” (Fletcher, 2016, p. 181). The traditional – positivist – view of the nature of science claims that research is and should be objective and ‘value-free’ (Bryman, 2012; Farthing, 2016). However, during the course of a general science-philosophical paradigm shift, this position was weakened by alternative views, which claim that all research is linked to subjective elements such as pre-conceptions or values (Allmendinger, 2002; Farthing, 2016). This paradigm shift is also observable in planning theory and planning research (Farthing, 2016).

Planning research underlies certain values (e.g., sustainability) or political views, and is driven by the wish for change or improvement (e.g., reduce transport energy use) (Farthing, 2016), which also marks the justification of a planning research agenda and the origin of related research questions. Hence, planning research cannot be separated from subjective elements.

The science-philosophical foundation of planning research is, however, also linked to a second debate: whether planning as a discipline is scientific or technological. Some scholars question the contribution of planning to research and theory building and instead consider it to be “focussed on achieving certain environmental and social goals” (Farthing, 2016, p. 16). In this context, this PhD study serves as a good example of how research (scientific) forms the foundation for the achievement of environmental goals (technological), while planning as a discipline contributes to and benefits from both purposes.

Critical realism has borrowed elements from both positivism and constructivism but, in contrast, “treats the world as theory-laden, but not theory-determined” (Fletcher, 2016, p. 182). Critical realism supposes causation, i.e. constraining and enabling factors, the results of which, however, depend on contexts and conditions (Sayer, 2001). Critical realism, hence, understands causal mechanisms as “social products that can ultimately be understood through – and indeed, that exist within – phenomena at the empirical level”, but that cannot be solely empirically identified (Fletcher, 2016, p. 183).

These suppositions make critical realism a valuable framework for the social sciences because social phenomena are considered to be “intrinsically meaningful” (Sayer, 2001, p. 2982). Naess (2015) considers critical realism to be particularly fruitful in urban planning and urban studies related research as it specifically serves the needs of planning research in providing the required knowledge for urban planning. This includes interdisciplinary integration, the investigation of “causal relationships between societal conditions, spatial urban structures and the actions of agents”, as well as generalisation and prediction (Naess, 2015, p. 1229).

Using the lens of critical realism for the present study allows causal relationships (the role of urban structure in travel behaviour) and reflecting on the social world people live in (role of socio-economic
Research design and methods

factors, attitudes, preferences, lifestyles, but also policy context) (Farthing, 2016) to be accounted for in an integrated manner in order to explain travel behaviour; hence, critical realism allows accounting for the spatiotemporal and social dimension of travel behaviour (see section 2.2.2). Travel behaviour is understood as “complexly composed effects of influences from different ‘mechanisms’”, which are activated and combined depending on structural influences and which may reinforce and counteract each other (Næss and Jensen, 2002, p. 297). Causal mechanisms are, consequently, not treated as static, but may be subject to changes.

Critical realism appears, thus, also as an adequate foundation to account for context-dependency, which is a major characteristic of case study research, while not precluding context-dependent generalisations (see below). Certain basic conditions of urban structure can be considered as generalisable, such as density or accessibility, although which and how specific mechanisms are activated by the structural conditions, and how these consequently generate specific travel patterns, requires a context-specific analysis. Hence, this study does not claim to identify general rules for travel behaviour, but to identify generalisable patterns or ‘tendencies’ (Næss and Jensen, 2002).

3.2 Study design

The posed research questions underlie different theoretical drives (Bryman, 2012; Morse, 2003). The first research question (paper I and II) has a rather inductive drive (“What role can urban planning play ...?”), whereas the second (paper III) and the third research question (paper IV) have a deductive drive (testing a theory: urban structure – travel behaviour). This is reflected in the chosen methods (section 3.3), which are predominantly qualitative in the first part, and predominantly quantitative in the latter part, feeding into a multimethod strategy (Morse, 2003).

The study applies case study research with the aim of investigating “a contemporary phenomenon (the ‘case’) in depth and within its real-world context” (Yin, 2014, p. 16). Two different multiple-case designs (Yin, 2014) were used for the different research questions. The selection of the cases was based on purposive sampling strategies (Kemper et al., 2003; Liampittong, 2009; Patton, 2002), whose underlying common principle is the selection of “information-rich cases” (Patton, 2002, p. 242).

The empirical part to the first research question (paper II) is based on typical (representative) cases, i.e. sites which are “not in any major way atypical, extreme, deviant, or intensely unusual” (Patton, 2002, p. 236), but which “exemplify a broader category of which [they are] a member” (Bryman, 2012, p. 70). The cases are the medium-sized Northern European cities Eskilstuna (Sweden), Turku (Finland) and Tartu (Estonia). These were also part of the EU-FP7 project PLEEC (Kullman et al., 2016). For this part, the analysis was conducted separately for each case and, subsequently, the three cases were compared (cross-case synthesis) (Thomas, 2011; Yin, 2014). This served to provide context-specific understandings (Flyvbjerg, 2006; Yin, 2014) and emphasise the role of context in urban planning.
The cases for the second and third research question (paper III and IV) were chosen *theory-based (deductive drive)* to exemplify and test theoretical assumptions, i.e. “the sample becomes [...] representative of the phenomenon of interest” (Patton, 2002, p. 238): The cases are an urban district in central Copenhagen (Østerbro) and a small town in the commuter belt of Copenhagen (Borup, Køge municipality), which represent two ‘paradigmatic’ types of urban structure (urban vs. peri-urban) with regards to travel behaviour.

A common criticism of case study research is that one cannot generalise from a single or a few cases (Flyvbjerg, 2006; Yin, 2014). Certainly, case studies cannot produce context-*independent* (universally valid) knowledge, but a case study allows the researcher to extrapolate from generated context-*dependent* knowledge to transferable knowledge for similar contexts and comparable settings (Flyvbjerg, 2006; Patton, 2002), framed by Neergaard (2007) as ‘*analogous generalisation*’.

### 3.3 Methods and data

The choice of the methods (see Table 1) was primarily guided by the research questions, but was also inspired by the methods commonly used in studies that deal with similar topics. The first research question (paper I and II) was investigated using multiple sources of evidence and data triangulation (Patton, 2002; Yin, 2014), including a literature review (section 3.3.1), a review of planning and policy documents, and expert interviews with civil servants and stakeholders including site surveys (section 3.3.2). The methods applied for the second and third research question (paper III and IV) include an online questionnaire survey (section 3.3.3) and the subsequent statistical analyses (section 3.3.4). The questionnaire contained also some supporting qualitative elements such as open-ended questions and room for comments.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Cases</th>
<th>Data sources</th>
<th>Literature review</th>
<th>Planning and policy documents</th>
<th>Expert interviews</th>
<th>Questionnaire survey</th>
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<tr>
<td>II</td>
<td>Turku, Tartu, Eskilstuna</td>
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<tr>
<td>III</td>
<td>Østerbro, Borup (Copenhagen Region)</td>
<td></td>
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<td>IV</td>
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The integration of qualitative and quantitative methods in a multimethod strategy was pursued in order to provide a rich and comprehensive set of sources, which appears to be suitable to the research
Research design and methods

topic. Finally, the choice of methods and data collection techniques reflect certain pragmatic decisions made in light of the technical limitations of a PhD study, such as time and financial resources, but also accessibility of cases and respective data, such as from the PLEEC project.

3.3.1 Literature review

During the initial phase of the PhD study (paper I and II), a comprehensive literature review was conducted to gain an overview and summarise the state-of-the-art of research on resource efficiency in cities and the relationship between urban structure and transport energy use and travel behaviour. The literature review was carried out as a narrative review (Booth et al., 2013) and it included conceptual and empirical work published in scientific articles and books, as well as policy-oriented documents and reports from the EU and other institutions ('grey literature').

The review of scientific literature was initiated by keyword searches in the main search databases (SCOPUS, ScienceDirect, REX5) and completed by using the "snowball technique" (Ridley, 2012, p. 56), i.e. based on bibliographies of core publications, key authors, and review articles. Books and book chapters were identified through the library system, REX. Finally, sensitivity checks (e.g. cross-checks of the relevant keywords in other search databases) were carried out to ensure that no essential contribution was missing.

Other references such as official documents, reports and 'grey literature' were collected by using internet search databases (Google) and the online libraries of relevant organisations (e.g., EU, EEA, OECD).

The literature search focused on the European context, but included further contributions, e.g., referring to North America and Australia, in case of general relevance.

3.3.2 Review of planning documents and expert interviews

The multiple-case study of Eskilstuna, Turku and Tartu (paper II) benefited from material, which was partly collected within the EU-FP7 project PLEEC (see also Fertner et al., 2015; Große et al., 2015; Groth et al., 2014); the sources include planning and policy documents, expert interviews and site surveys. The author of this thesis participated in all parts of the data collection.

Review of planning and policy documents

The reviewed documents comprise local planning and policy documents (and selective previous versions or drafts of new versions) that address issues of spatial development, transport, climate and energy planning. Planning and policy documents of superordinate levels (regional, national) were included if relevant for local planning (see Appendix of paper II).

The planning and policy documents were used to gain a basic understanding regarding what issues/topics – with regards to energy and transport planning – are covered in the documents, how the

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5 library system of the University of Copenhagen, provides access to all major public and academic libraries in the Nordic countries
issues/topics are addressed in the documents (e.g., general objectives, strategies, planning instruments) and if/how the policy and planning documents are related to each other.

Most documents were available in English, otherwise local project partners assisted in their translation.

*Expert interviews*

The expert interviews with civil servants and stakeholders in urban development and energy planning were conducted as part of field visits of 2-3 days to each case city between March and June 2014. The selection and recruitment of interviewees was carried out in cooperation with the respective contact persons of the PLEEC project in each city in order to cover a broad spectrum of *insiders’ views* with regards to urban spatial, energy and transport planning. The interviews were held in English with 1-3 participants from the respective city/stakeholder department or institution (7 interviews in Eskilstuna, 4 interviews in Tartu, 5 interviews in Turku); each interview lasted 1-2.5 hours and was conducted at the interviewees’ facilities (see Appendix of paper II).

The expert interviews took the form of *in-depth interviews*, which allow "researchers to make sense of the multiple meanings and interpretations of a specific action, occasion, location, or cultural practice" (Liamputtong, 2009, p. 43). The interviews were semi-structured (Bryman, 2012), following the *‘Interview guide approach’*, which ensures that "the same basic lines of inquiry are pursued" in each interview, but "the interviewer remains free to build a conversation within a particular subject area" (Patton, 2002, p. 343). The interviewees were asked about national energy regulations and framing conditions, the evolution of spatial planning, current transport planning, energy management and supply, as well as national and local energy policy and the role of regional planning.

All interviews were audio-recorded and transcribed. The analysis of the interviews was guided by *qualitative content analysis*, which is a systematic method of text analysis and interpretation, which is based on the use of categories (Mayring, 2000). The interview transcripts were coded manually with the assistance of software (QSR NVivo) by using keywords and split into analytical categories (e.g., urban structure, municipal planning, cooperation).

### 3.3.3 Questionnaire survey

A core part of this study is an online questionnaire survey, which was carried out in May and June 2016 in Østerbro (a district in the municipality of Copenhagen) and in Borup (a small town in the municipality of Køge, both in Denmark). Denmark is among the countries with the highest internet access rates in Europe; 94% of the Danish households had access to the Internet in 2016, compared to the European average of 85% (European Commission, Eurostat, 2016). As a benchmark of 80% internet penetration is considered sufficient (Grönlund and Strandberg, 2014), and considering the targeted age group (18-65 years), an online survey (using SurveyXact) was judged to be an appropriate method.
Research design and methods

Questionnaire design

The questionnaire follows a type of data collection including a mixture of quantitative and qualitative (open-ended) questions (Johnson and Turner, 2003). The questions were based on parameter sets of previous studies on urban structure and travel behaviour and were complemented by additional parameters on free time, weekend and holiday travel, living environment, and attitudes (e.g. Banerjee and Hine, 2014; Dieleman et al., 2002; Lim, 2016; Næss, 2009, 2006b; Næss and Jensen, 2004; Silva et al., 2015). Also, nationwide statistics such as The Danish National Travel Survey (Christiansen and Skougaard, 2015) and Statistics Denmark were considered. In contrast to what is commonly applied in travel surveys, people were asked about their ‘usual’ behaviour (related to the past 12 months) to avoid seasonal bias as the sampling period was limited to the spring of 2016. The questionnaire (see Appendix) comprised questions regarding:

- car use in general,
- daily travel behaviour to work/education and in free time,
- free time activities,
- weekend, holiday and plane trips within the past 12 months,
- people’s living conditions and environment, including personal satisfaction with specific features of the living environment,
- summer cottage access and use,
- moving,
- general statements on attitudes related to travel behaviour, environmental friendliness and living environment, and
- socio-demographic and socio-economic background parameters.

The questionnaire was available both in Danish and English. The length of the questionnaire was almost 15 minutes on average, which is relatively demanding and may explain the limited response rate (see below).

As the questionnaire is a “self-report data collection instrument that is filled out by the research participants” (Johnson and Turner, 2003, p. 303), all questions needed to be explicit, unambiguous and unmistakable. Therefore, the questionnaire passed (in both languages) through three phases of pre-testing: expert advice, a pilot test in April 2016, for which the questionnaire was distributed to colleagues and to their families and friends, and final checks (Vaske, 2008).

Sampling method

Mainly due to practicalities, two different sampling methods were applied in Østerbro and Borup. In Østerbro, an online panel provider (Userneeds) was employed to distribute the questionnaire survey via e-mail to 757 households. The response rate (Vaske, 2008) of completed surveys was 31.7%. Outside the big cities, panel providers cannot offer sufficient sample sizes. Therefore, in Borup on 25th and 26th May 2016, my colleagues and I delivered written invitations with a link to the online question-
naire to each household, except housing for elderly people and nursing homes ('plejahjem'). In total, 1,874 households received an invitation. The response rate of completed surveys in Borup from the letter invitations was 9.3%. Additional advertisements were placed in the local newspaper (Lørdagsavisen, 2nd June 2016), the local library and supermarkets in Borup to promote and access the survey. The additional advertisements included a different link so that the respondents could be distinguished from each other later on.

The questionnaire was designed to be answered by one person per household, aged between 18 and 65 years, in order to focus on the working population. Respondents outside this age group were included for the data analysis if they were part of the working population. Due to these limitations, some responses from Borup and one from Østerbro were discarded from the data analysis. The final sample consists of 239 complete responses in Østerbro and 157 in Borup (13 from the additional advertisements). Furthermore, 23 partially completed responses in Østerbro and 20 in Borup (two from the additional advertisements) were included in the final sample, summing up to 439 responses in total.

The sampling method applied in Borup (written invitation to each household) corresponds to probability-based sampling (non-list-based random sampling), which is considered to involve less bias (Bryman, 2012; Fricker, Jr, 2008). The sampling method applied in Østerbro (panel) corresponds to non-probability sampling as it made use of a volunteer (opt-in) panel (Fricker, Jr, 2008). According to the panel provider (Userneeds A/S, 2016), however, representativeness of the samples is provided as no active subscription to the panel is possible, but recruitment is aligned with continuous analysis of the demographic composition of the panel. Furthermore, Grönlund and Strandberg (2014, p. 101) found that "some degree of skewness [...] is to be expected regardless of the sampling method"; and they could not find any proof that probability-based sampling is suitable for counteracting non-representativeness in online panels. The application of two different sampling methods and their representativeness was considered in the interpretation of the results.

3.3.4 Descriptive, bi- and multivariate statistics

For the quantitative data analysis (questionnaire data), methods of descriptive, bi- and multivariate statistics were applied. Descriptive statistics were mainly used for the initial characterisation of the studied variables, to identify outliers and potential data entry errors, and for data presentation purposes.

In paper III, the statistical analysis was carried out by using clustering techniques (hierarchical, TwoStep, manual) and subsequently tests of association and comparison (Pearson’s Chi-square, Kruskal-Wallis H). Cluster analysis is a procedure that is typically used for segmentation or building typologies of data (Schendera, 2010) and it was, therefore, applied to build groups of ‘modality styles’ among the respondents to the questionnaire. Tests of association and comparison were, subsequently, used to identify group differences with regards to a set of parameters (e.g., socio-economic factors, weekend trips, holidays, and travel-related attitudes).
Research design and methods

The statistical analysis of paper IV was performed with ordinal regression models (cumulative odds ordinal logistic regression with proportional odds). Ordinal logistic regression is used to predict an ordinal dependent variable, and to determine which of the predictors (independent variables) have a significant effect on the dependent variable (Laerd Statistics, 2015; Norušis, 2011; Schendera, 2014). The ordinal regression models were used to determine the influence of different factors (e.g., residential location, summer cottage access, car ownership, income, education, satisfaction with living environment) on the number of weekend, holiday and plane trips within the past 12 months (= ordinal dependent variables). Furthermore, a Mantel-Haenszel test was used to determine whether there was a relationship between the number of weekend trips and holiday trips.

The statistical analyses were conducted using IBM SPSS Statistics 22 and 24, and XLSTAT 2017.

3.4 Introduction to the studied cases

3.4.1 Turku, Tartu and Eskilstuna (Paper II)

The three case cities Turku (Finland), Tartu (Estonia) and Eskilstuna (Sweden) (see Figure 6, Table 2) feed into the inductively driven part of the study. The first research question (paper I and II) aims to gain a comprehensive and in-depth understanding of the role of urban planning, which requires selecting comparable and representative as well as ‘feasible’ cases (paper II) that can be treated in their entirety and allow the deployment of multiple data sources.

![Map of Northern Europe showing Turku, Tartu, Eskilstuna, Helsinki, Stockholm, Tallinn and Estonia](image)

Figure 6: Three case cities and urban areas in Northern Europe (data source: EEA, 2015b; see Große et al., 2016)

The cases were chosen based on certain similarities, such as city size (medium-sized), location (Northern Europe), function (regional centres), planning system (strong municipal planning level, rather
weak regional level) (COMMIN Project Co-ordination, 2015; Smas and Fredricsson, 2015) and style of spatial planning (comprehensive integrated approach) (ESPON, 2007) as well as similar problems and challenges (e.g., urban sprawl, regional commuting).

Figure 7: Turku centre (source: Juliane Große)

Figure 8: Tartu residential areas (source: Niels Boje Groth)

Figure 9: Eskilstuna residential area (left) and centre (right) (source: Niels Boje Groth)

Moreover, the cases illustrate the role of context, such as divergent urban dynamics and development challenges, or administrative area and specialities in the respective planning systems and national contexts. According to their characteristics, the cases can, to some extent, be considered as ‘repre-
sentative’ or ‘typical’ of medium-sized European cities. Europe6 has a rather polycentric structure and medium-sized cities are a characteristic phenomenon (Nordregio et al., 2005).

Table 2: Key figures of Eskilstuna, Turku and Tartu (data source: European Commission, Eurostat, 2016; Giffinger et al., 2014; see Große et al., 2016)

<table>
<thead>
<tr>
<th></th>
<th>Eskilstuna</th>
<th>Tartu</th>
<th>Turku</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhabitants in the municipality</td>
<td>99,804</td>
<td>97,847</td>
<td>180,225</td>
</tr>
<tr>
<td>Inhabitants in the urban region</td>
<td>(99,804)7</td>
<td>150,528</td>
<td>316,634</td>
</tr>
<tr>
<td>Administrative area of the municipality in km²</td>
<td>1,100</td>
<td>39</td>
<td>245</td>
</tr>
<tr>
<td>Urban area of the municipality in km²</td>
<td>51</td>
<td>29</td>
<td>75</td>
</tr>
<tr>
<td>Population density in inhabitants per km² urban area</td>
<td>1,945</td>
<td>3,396</td>
<td>2,403</td>
</tr>
<tr>
<td>Average number of persons per household</td>
<td>2.2</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>GDP per capita in NUTS 3-region in Euro (2012)</td>
<td>35,500</td>
<td>9,300</td>
<td>33,800</td>
</tr>
</tbody>
</table>

3.4.2 Østerbro and Borup in the Greater Copenhagen Region (Paper III and IV)

The two cases Østerbro and Borup in the Greater Copenhagen Region (Denmark) feed into the deductively driven part of the study. The second and third research question (paper III and IV) investigate very specifically the relationship between urban structure and travel behaviour. This required selecting ‘paradigmatic’ cases according to the theoretical assumptions (role of urban structure in travel behaviour), but controlling for some ‘meta-conditions’, such as geographic context, general welfare level and planning culture.

Copenhagen is, besides other cities, often referred to as the ideal regarding sustainable urban structure and transport (Beatley, 2004; Girardet, 2004; Zipori and Cohen, 2015). The Greater Copenhagen Region, therefore, provides a suitable meta-setting from which two paradigmatic cases were selected (see Figure 10).

Østerbro had a population of about 76,800 inhabitants in March 2016 (Københavns Kommune, 2016) and an area of 8.74 km²; Borup had a population of about 4,600 inhabitants in 2016 (Statistics Denmark, 2016) and an area of 2.6 km². They represent two distinct types of living environment in terms of urban structure. The urban district of Østerbro in Copenhagen represents ‘central urban living’, while the small town (‘stationsby’8) of Borup in the commuter belt of Copenhagen represents ‘peri-urban small town living’.

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6 In the EU, 611 of the 732 cities have a size of 50,000-250,000 inhabitants, only 7% of the EU population live in cities of more than 5 million inhabitants (European Commission, 2011a)
7 The administrative area of Eskilstuna is congruent with its urban region (see Figure 6).
8 ‘Stationsby’ is Danish for a small town (originally) with a railway station. It is commonly used for approximately 400 town settlements in Denmark that emerged between 1840 and 1940 and relates to a specific historic context (Groth and Fertner, 2013).
The differences in urban structure between Østerbro and Borup are characterised by, e.g., housing density and housing types (apartment vs. detached houses), accessibility of facilities and public transport, distance to a regional centre as well as availability of green spaces (e.g., garden, nature areas). The cases show comparable socio-economic profiles (e.g., income, workforce participation), which allows maximising the explanatory power of urban structure and highlighting further relevant factors, such as lifestyle-related attitudes or preferences. The cases represent two types of urban structure that exist in similar forms in other places in Europe, which facilitates the generation of transferable results and conclusions with relevance to comparable contexts.
Against the backdrop of the final objective of this study regarding implications for urban planning, one could argue that the developed framework on the role of urban planning (paper I and II) cannot be related to the results that are derived from the Copenhagen study (paper III and IV). However, firstly, the planning systems of the concerned countries, Denmark, Sweden, Finland and Estonia, are similar, e.g., characterised by a strong municipal planning level (COMM IN Project Co-ordination, 2015). Secondly, the developed framework on the role of urban planning specifically allows and accounts for differences in possible preconditions. And thirdly, the selection of cases aimed at representativeness in both parts of the study; hence, the results of the study claim to be of general relevance to similar settings. Therefore, context-dependent generalisable implications for urban planning may well be derived from the results. This is done in the discussion of this thesis (see chapter 5).
4 Introduction to the scientific papers

This chapter provides an introduction to the objectives, research questions, methods and main findings of each of the four scientific papers that were developed as part of this PhD study.

Paper I: Compact and resource efficient cities? Synergies and trade-offs in European cities

The first paper, to which I contributed during the initial phase of this PhD study, is a literature review of resource efficiency and compact cities, elaborating particularly on the benefits of the compact city, and including considerations on trade-offs and rebound effects. The literature review summarises the main benefits of compact urban structures, which include minimising land use, decreasing travel demand and energy use for transport, as well as efficient use of infrastructure and resources. Moreover, the importance of scale and the embedding of cities in their respective functional urban areas are emphasised. This becomes especially relevant for polycentric interpretations of the compact city, as in the studied European context. The derived perspectives highlight spatial planning principles and touch upon the necessity of accompanying measures such as public transport. The findings also highlight drawbacks of the compact city, such as the potential for rebound effects with regards to the consumption of services and products as well as compensatory activities.

The results of the paper helped respond to the first research question regarding the role of urban planning in dealing with urban structure.

Paper I was driven by an explorative objective to enter the topic of urban structure and formed as such an important basis for the research background of paper II and the thesis. My contribution to this paper comprised the completion of the literature review, which provided an ideal starting point for addressing the research problem.

Paper II: Urban structure, energy and planning: Findings from three cities in Sweden, Finland and Estonia

Paper II can be considered an in-depth and more focused (on transport planning) examination in continuation of paper I. The objective of paper II was to conceptualise the scope and key framing conditions (potential and constraints) for urban planning, especially in transport planning, which was achieved by combining a literature review with empirical work.

The core of paper II is a multiple-case study of the three medium-sized cities Turku (Finland), Tartu (Estonia) and Eskilstuna (Sweden). By means of qualitative methods (expert interviews, review of planning and policy documents, site surveys), which complement insiders’ views and planning ‘documentation’, the paper aimed to gain an understanding of the role of urban planning with regards to dealing with urban structure and transport planning.

All three case cities demonstrate that addressing regional, especially car-dependent, commuting as a consequence of urban sprawl and regional enlargement is a major challenge. Travel patterns are in-
trinsically tied to a city's position in the regional urban system. However, a municipality’s administrative boundary restricts the territorial scope of urban planning, which may – as in Turku and Tartu – hardly comprise the contiguous built-up area, or – as in Eskilstuna – even cover the closer rural hinterland, i.e. the functional urban area. Furthermore, the case cities illustrate the differences in commitment to sustainability as well as local power relations, i.e. the involvement of stakeholders and coordination between municipalities. For instance, in Eskilstuna, even though the planning documents include purposively adopted strategies that account for the wider territorial scope and that are carried out with stakeholders, energy efficiency remains a ‘second-order’ policy compared to ‘first-order’ economic interests, which are reflected in regional enlargement and increased transport.

Thus, a first finding of the paper concerns the role of urban structure, which is limited to promoting but not constituting energy savings. Consequently, the paper confirms the importance of ‘complementing’ or ‘accompanying’ measures and policies for optimising urban structure as well as the necessity for regional cooperation as, for instance, transport exceeds municipal boundaries and represents functional relations. Departing from these observations, paper II developed a framework for the role of urban planning. Urban planning is, accordingly, understood as acting with and within the three dimensions of urban form/spatial structure, functional relations and policy context. This framework was introduced in section 2.4 as part of the research background.

The development of paper II benefitted from work that was conducted as part of the PLEEC project. The review and empirical research were fundamental for developing clarity and understanding with regards to the concepts and terminology in the field of urban structure, transport energy use, urban planning and transport planning. Hence, paper II made a substantial contribution, in continuation of paper I, to answering the first research question regarding the role of urban planning.

**Paper III: Linking daily travel behaviour with weekend and holiday travel: Exploring the role of modality styles and urban structure in Greater Copenhagen**

In contrast to the more explorative-inductive approach of paper I and II, paper III and IV have a clear deductive approach. Both papers are guided by theoretical assumptions regarding the influence of urban structure (residential location) on travel behaviour, which determined the selection of the two case areas. The objective of both papers was to explore the role of the urban structure of people’s living environment and further explanatory factors in their travel behaviour in terms of daily travel patterns (modality styles) and weekend/holiday travel.

The study is based on a questionnaire survey that was conducted in spring 2016 in Østerbro, a district in central Copenhagen, and Borup, a small town in the Greater Copenhagen Region.

The analytical approach utilises the concept of *modality styles* for grouping the respondents from both case areas into clusters of similar daily mode choices. Based on the daily transport mode choices for work and leisure, the study identifies four distinct modality styles, of which two are clearly linked to a certain urban structure: the *committed cyclists*, who are almost exclusively represented in Østerbro,
and the ‘die-hard’ car drivers, the majority of whom are represented in Borup. The other two modality styles – public transport users (work) and non-public transport users (using a mix of modes except public transport) – are represented in both case areas.

Subsequently, the four identified modality style-groups have been compared in terms of socio-economic and socio-demographic differences, their weekend and holiday travel behaviour (frequency, transport modes) as well as their travel-related attitudes, using statistical techniques for analysing group differences. It transpired that meaningful patterns between daily modality styles and weekend/holiday travel behaviour could only be detected when, besides the modality style, residential location was accounted for. The committed cyclists most frequently undertake weekend and holiday trips, while there is an overall tendency for more weekend/holiday trips among the respondents from Østerbro. In terms of the chosen travel mode for weekend and holiday trips, the results reveal a similar dichotomy: The ‘die-hard’ car drivers stick to the car, while the committed cyclists tend to use the plane (besides the car and sometimes public transport), and the public transport users behave according to their ‘residential peers’. Overall, the use of public transport plays a minor role in weekend and holiday travel. The differences between the groups regarding the respondents’ attitudes towards the environmental friendliness of daily transport modes largely confirm the corresponding modality style, i.e. cyclists have the ‘greenest’ attitude, whereas car drivers have the least ‘green’ attitude. However, when it comes to weekend/holiday travel, the results reveal the cyclists have an escapist attitude: Contrary to the stated ‘green’ attitude, they show comparably high trip frequencies and plane use.

Paper III answers the second research question on how daily modality styles correspond with weekend/holiday travel and elaborates on the role of urban structure and further determinants in the observed travel behaviour. The study discusses the influence of urban structure as compared to residential location and of further – to some extent underlying – factors, such as socio-economic factors, lifestyles or life stages, on travel behaviour. The paper, thereby, contributes to a more comprehensive understanding of travel behaviour across different travel domains and adds knowledge about the drivers that underlie travel behaviour as a reflection of the role of residential location versus urban structure.

*Paper IV: Compensating for Compactness? Leisure Travel of City Dwellers vs. Small Town Dwellers in Greater Copenhagen*

Paper IV focuses on the role of urban structure in weekend/holiday travel. Taking the ‘compensation hypothesis’ as the starting point, the paper looks at differences in peoples’ weekend and holiday travel behaviour between the central urban district of Østerbro and the small town of Borup.

The paper is based on the questionnaire survey that was also used in paper III, which facilitates a cross-paper discussion of the results (see chapter 5). The analysis was based on ordinal regression to examine the influence of a set of variables on the frequency of weekend, holiday and plane trips, which were all dependent variables.
Introduction to the scientific papers

As already shown in paper III, the respondents from Østerbro go on weekend, holiday and plane trips more frequently. Furthermore, the study identified a link between summer cottage\textsuperscript{9} access and weekend trips in Denmark/Skåne\textsuperscript{10}; in combination with the stated motives for undertaking trips, this indicates some sort of compensatory travel among the city dwellers. However, holiday and plane trips have to be considered mainly as the result of personal preferences and a certain lifestyle. The study found a positive association between the number of weekend trips and holiday trips and, hence, some people appear to have a preference for travelling, whereas others do not.

In response to the third research question, paper IV identifies differences in people’s weekend and holiday travel behaviour between the two residential locations and qualifies the effect of ‘compensation’ in relation to other factors, such as socio-economic factors or lifestyle, to explain the observed differences.

\textsuperscript{9} Summer cottages (Danish: ‘sommerhuse’) are a popular type of second home (shared or owned) in Denmark, which are visited at the weekends or on holidays. They are typically located in settlements of summer cottages. In 2016, there were more than 220,000 summer cottages in Denmark compared to a population of 5.7 million (Statistics Denmark, 2016).

\textsuperscript{10} Skåne (English: Scania) is the southernmost county of Sweden, which can be considered as part of the Greater Copenhagen Region based on distance, see Figure 10.
5 Results and discussion

The results of the study have been presented and discussed in detail in the individual papers and re-capped in chapter 4. This chapter focuses on a cross-paper summary and discussion, also in relation to previous studies, of the results that are most relevant in relation to each other and in terms of the overall contribution of this PhD study.

5.1 The role of urban planning with respect to urban structure

Investigating the relationship between urban structure and travel behaviour entails discussing the role of urban planning as urban structure is one of the inherent preserves of urban planning. Therefore, the first part of the study (paper I and II) focused on conceptualising the scope as well as potential of and constraints on urban planning, especially regarding transport. The findings illustrate that:

- Working with urban structure requires the implementation of ‘complementing’ or ‘accompanying’ measures and policies (e.g., public transport), which is in line with previous findings (e.g. Banister, 2008; Næss, 2006a). At the same time, urban planning practice is often limited to such policies and measures because substantial changes in urban structure are hard to implement.

- Hence, it could be observed that the pursued urban planning strategy involves focusing on such accompanying policies/measures in order to optimise and modify the given urban structure. The organisation of public transport turns out to be a crucial complementing policy, which confirms earlier findings (e.g. Cooper et al., 2001a, 2001b; Rickwood et al., 2008).

- Functional relations such as transport require regional cooperation, but the territorial scope of urban planning is confined by its municipal borders; thus, when the regional level – as in the studied cases – is rather weak, planning beyond the borders relies on voluntary cooperation between the municipalities (see Jørgensen and Årø, 2007; Lundqvist, 2015).

Based on the findings from the literature review and the empirical results from Turku, Tartu and Eskilstuna, the role of urban planning was conceptualised as acting with and within the three dimensions of urban form/spatial structure, functional relations and policy context. This serves as a conceptual frame for deriving – to a certain extent generalisable – implications for urban planning in order to address travel behaviour (see section 5.4).

5.2 Qualifying the role of urban structure

Existing studies and own empirical work on Turku, Tartu and Eskilstuna have illustrated the potential (minimising land use, reducing travel, and efficient use of infrastructure and resources), drawbacks (sustainability trade-offs and compensatory travel) and limitations (e.g., non-bounded trips) of compact urban structure. Compact urban structure and complementing policies reflected in respective spatial planning principles can, thus, be considered as necessary precondition for facilitating efficient (transport) energy use in cities. However, the way people travel cannot be sufficiently explained by
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urban structure (e.g. Næss, 2006a; Pinho and Silva, 2015; Silva et al., 2015; Stead and Marshall, 2001). This has been demonstrated even more for non-bounded trips. In order to gain a more comprehensive understanding of travel behaviour and the role of urban structure in different travel domains, the study looked at daily modality styles in the urban district of Østerbro, and the small town of Borup. In Østerbro and Borup, the identified four modality styles show that in daily travel, bicycle and car use have a strong urban structure component, as represented in Østerbro and Borup, respectively, whereas other factors may play an equally important role for public transport use. These findings are largely consistent with previous studies: For the Copenhagen Region, Prato et al. (2016, p. 1) identified four – also in terms of their spatial representation – similar ‘lifestyle groups’: “car oriented, bicycle oriented, public transport oriented and public transport averse”. Olafsson et al. (2016) confirm that, in Denmark, cycle-based travel predominately takes place in larger urban areas, whereas car-based transport is dominant in small urban/suburban areas. This transport mode-divide between urban (cycling, walking) and peri-urban areas (car) has also been confirmed for the Copenhagen region (Næss, 2006a).

For Østerbro and Borup, when the identified modality styles were, subsequently, related to weekend and holiday travel, it became evident that the influence of urban structure is largely limited to daily travel (bounded trips). This reveals limitations for addressing travel behaviour comprehensively through urban structure and, hence, illustrates limitations for urban planning.

Paper III and IV revealed that city dwellers (Østerbro) go on weekend and holiday trips more frequently than small town dwellers (Borup). Accordingly, linking weekend and holiday travel (frequency) to the four modality styles only delivered meaningful results when residential location was accounted for as an additional layer. The results revealed a similar pattern regarding transport modes on weekend and holiday trips: city dwellers use the plane more frequently, whereas small town dwellers prefer to use the car.

Overall, it appears that urban cyclists have the most energy-intensive weekend and holiday travel behaviour in terms of frequency and mode choice. However, this does not imply that urban structure explains increased weekend and holiday travel; rather it only suggests that the underlying drivers may be directly or indirectly linked to residential location. For instance, socio-economic differences (e.g., income per person, household size) are expressed between the two residential locations (Østerbro vs. Borup) rather than between the modality styles. This indicates that certain lifestyles, which may be related to certain life stages, are predominantly represented in either cities or small towns.

Moreover, paper IV found that the effect of compensation, as a response to a dense and compact urban environment, is limited. Only weekend trips to a summer cottage can be considered as some sort of compensatory behaviour, at least for the case of Østerbro, which is in line with the results of some studies (e.g. Dijst et al., 2005; Strandell and Hall, 2015), but is contested by a previous study on the Copenhagen region which does not arrive at such explicit results (Næss, 2006b). The importance of summer cottages in weekend trips and holidays, which are also some sort of cultural phenomenon in
Denmark and other Nordic countries, has been acknowledged in previous studies and, moreover, discussed as being a less energy-intensive alternative to long-distance holidays. However, people with access to summer cottages do not appear to undertake less travelling to other destinations (Christensen, 2014).

5.3 What constitutes travel behaviour?

The combination of the results from paper III and IV confirms that diverse drivers, determinants and their interplay constitute travel behaviour. Their influence differs between work and leisure travel and is particularly pronounced between daily travel (work and leisure) versus weekend and holiday travel. This corresponds to the notion of bounded compared to non-bounded trips (Næss, 2006a; Vilhelmson, 1999): The urban structure of a residential location is an important constituent of daily travel behaviour. However, for weekend and holiday travel, residential location and urban structure play an ambiguous role.

According to the study’s results, compensation only explains a small share of more extensive weekend/holiday travel among city dwellers. Rather, a combination of socio-economic and socio-demographic factors, lifestyle and personal preferences – which also underlie residential choices and are, therefore, represented in different residential locations – explain weekend and holiday travel in terms of trip frequency and mode choice (plane vs. car use). A link between trip activity and lifestyle, socio-economic factors (e.g., income, household size) or life stages (e.g. Böhler et al., 2006) as well as more long-distance travel, especially air travel, among urban dwellers (e.g. Frändberg and Vilhelmson, 2003; Holz-Rau et al., 2014; Reichert et al., 2016; Reichert and Holz-Rau, 2015) have also been found in previous studies. Both the findings of this study and those of previous studies suggest that travelling is part of an urban ‘cosmopolitan’ lifestyle (e.g. Holden and Norland, 2005; Næss, 2006b; Reichert et al., 2016).

The obtained results on differences in weekend and holiday travel between urban and small town dwellers imply two relevant associations: The first concerns rebound effects: Although, compensatory travel, here conceptualised as direct rebound effect, appears to play a minor role, the observed weekend/holiday travel behaviour among the respondents from Østerbro indicates indirect rebound effects, which are expressed in additional consumption, i.e. travelling, as also previously suggested (e.g. Holz-Rau et al., 2014). A second association concerns the relevance of residential self-selection, i.e. it is not necessarily urban structure that makes the difference, but rather the underlying lifestyles and personal preferences for a certain residential location. People with certain (cosmopolitan, travel-oriented) lifestyles or who are at certain life stages (without children) possibly prefer living in the city, whereas people with less travel-oriented, but family-oriented lifestyles prefer to move out of the city (see Aner, 2016; Fertner, 2013; van Acker and Witlox, 2009).

The public transport users among the identified four modality styles reveal a further ‘residential-location-gap’ as they behave like their ‘residential peers’ in terms of car and plane use for weekend
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and holiday travel: The public transport users from Østerbro have, like the cyclists, a tendency to use the plane, whereas the public transport users from Borup prefer to choose, like the car drivers, the car. Car ownership appears to influence car use: Respondents who have a car and use it for daily transport seem to prefer to also use it for weekend/holiday travel; this is confirmed by previous studies (e.g. Lanzendorf, 2002; Silva et al., 2015). In contrast, less access to cars, as among the respondents of Østerbro, apparently does not lead to fewer trips, but instead increases plane use. Hence, the ‘residential-location-gap’ regarding mode choice for weekend and holiday travel is related to car ownership, which differs between residential locations, and this gap is possibly further promoted by access to an airport; e.g., Bruderer Enzler (2017) found more frequent air travel related to airport accessibility.

Additionally, the choice of travel destination is probably influenced by car ownership and airport accessibility; either in favour of destinations that are accessible by car (if a car is already available), or the reverse, destinations that require a plane. Destination choices suggest, again, linkages to lifestyles and life stages: Families with children would probably rather choose – with regards to price and practicalities – destinations that are not too distant and accessible by car; as also found by Davison and Ryley (2013). In contrast, cosmopolitan city dwellers without children may prefer – and be able to undertake – destinations that require taking a plane.

Finally, the results reveal that attitudes towards environmental friendliness do not necessarily correspond to travel behaviour. Attitudes and behaviour are largely congruent in daily travel: For cyclists, environmental friendly daily transport modes are important, whereas car drivers agree less with that. However, regarding weekend and holiday travel, the ‘green’ daily travellers’ (cyclists) behaviour contradicts their ‘environmentally friendly’ attitude. Hence, attitudes appear to fall short of determining travel behaviour, or aligning leisure travel with environmental attitudes seems to be particularly difficult; a conclusion which has also been reached in earlier studies (e.g. Holden and Linnerud, 2011).

The synopsis of the results shows that a combination of urban structure, socio-economic factors, lifestyle and life stage, attitudes, car ownership/use and access to an airport as well as the interplay between them explain travel behaviour. To complicate matters, these factors are, to some extent, directly (e.g., urban structure) or indirectly (e.g., socio-economic factors) related to and ‘masked’ by residential location (see van Acker et al., 2011; van Acker and Witlox, 2009). Thus, the influence of urban structure is difficult to isolate from the influence of other factors, although the results indicate that some factors are more relevant for daily travel (urban structure), whereas others are more relevant for weekend or holiday travel (household size, disposable income, car ownership vs. airport accessibility, lifestyle).

5.4 Implications for urban planning for sustainable transport

As indicated earlier, the ambiguous role of urban structure, besides other factors that explain travel behaviour, creates a dilemma and challenge for urban planning. Evidently, daily and weekend/holiday
travel behaviour are not disconnected from residential location, i.e. urban structural settings, but the underlying drivers are only within the scope of urban planning to a limited extent. Nevertheless, also for types of travel where urban structure, and hence urban planning, appear to have a limited influence, the study intends to advocate the role and potential of urban planning instead of just passing the ‘policy homework’ for sustainable transport planning to higher tiers of planning and policy-making. A reasonable question to ask is how urban planning can change lifestyles or preferences. Instead of focusing on changing lifestyles, a more appropriate question would be how to provide living conditions that better accommodate people’s preferences, while at the same time facilitating sustainable behaviour.

The observed phenomenon of more weekend/holiday travel among city dwellers, which is partly compensatory, illustrates the complexity and limitations of planning outcomes. The example of Copenhagen is striking – its ‘green travellers’ rebound in weekend and holiday travel. Thus, there is a demand for complex planning instruments in different planning settings and situations with respect to policy context and functional relations. The results of this study have led to the formulation of some recommendations for urban planning to address (in cooperation with other municipalities):

- A significant group of people never uses public transport for daily travel, which is probably also linked to car availability and the fact that local/regional public transport does not meet people’s transport needs (see Thøgersen, 2006). The latter was also stated by some residents of Borup in the questionnaire on travel behaviour.
- Similar reasons are likely to explain the minor role public transport plays in weekend trips or holidays; moreover, access to an airport is possibly a strong competitor.
- Summer cottage use, which could be identified as some sort of compensatory travel, is certainly also a cultural phenomenon, at least in some Nordic countries. This makes it difficult to address, but it may be made more sustainable regarding the summer cottage settlements themselves (see Nørgaard, 2017), but also their accessibility by (regional) public transport.
- Urban planning faces the complexity of residential choice. Travel behaviour cannot be disconnect-
ed from residential choices or underlying preferences. Urban planning that is guided by principles for quality of life embedded in sustainable urban structure, such as affordable, family-friendly housing with (semi-)private green spaces, opportunities for leisure activities in the city and high-quality public green spaces (see Naess, 2006a), might, firstly, prevent people from moving out of the city (e.g. Aner, 2016) and turning to unsustainable daily travel, and, secondly, contain compensatory travel.
- Finally, involving people, raising awareness and addressing individuals’ responsibility for the environmental impacts of their behaviour (e.g. Banister, 2008) may be promoted by urban planning.

Overall, the empirical results of the study reflect – in terms of implications for urban planning – the initially outlined three dimensions of urban form/spatial structure, functional relations and policy context that frame urban planning. Transport exceeds the municipal area: functional relations as regards
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daily travel and even more (non-bounded) weekend or holiday travel cross municipal borders. This requires – regional or even national – cooperation to, for instance, strengthen public transport. Urban planning can ‘deliver’ urban structure and related policies within its municipal scope, but residential choices and summer cottage use, for instance, occur on a wider regional scale.

5.5 Travel behaviour beyond urban planning

As stated in the introduction to this thesis, adapting travel behaviour requires structural changes. Throughout the thesis, it has been demonstrated that urban planning can, through urban structure and complementing measures, facilitate or encourage certain – desired – travel behaviour, particularly in terms of daily travel. Nevertheless, in addition to the necessary share of urban planning, travel behaviour underlies drivers that require steering from higher tiers of governance. Frequently suggested measures include regulatory and pricing policies (e.g., personal carbon budget, climate gas compensation schemes), which internalise the external costs of travel, incentives, or regulation of car ownership (e.g. Banister, 2008; Borup, 2009; Naess, 2006a; van Acker et al., 2016; van Wee, 2007).

The example of Østerbro illustrates that for weekend/holiday travel the use of car and plane is an intertwined problem. Car ownership and, hence, car use are already limited in Østerbro. The high costs of owning a car compared to the relative advantages of other available transport modes (cycling, plane) shifts car use to other modes (plane). Hence, regulating car ownership alone falls short, but regulatory measures, such as higher fuel prices, which affect car use (van Wee, 2007) might be similarly effective for plane use (see Peeters et al., 2006). Air travel has been found to be even more sensitive to income than other transport modes (Knudsen, 2014). The inclusion of air travel in 2012 in the EU Emissions Trading System (EU ETS) was a promising start, although its expansion to flights to and from the European Economic Area (EEA) has already been postponed beyond 2016 (European Commission, 2016).

Moreover, addressing car and plane use implies promoting a modal shift (e.g. Banister, 2008), e.g., towards public transport use, which appears underutilised for weekend and holiday travel in the studied cases. The study did not investigate the reasons for this, but public transport probably cannot keep up with the plane or car in terms of reliability, convenience, time efficiency and price (van Goevertden, 2007). Promoting a modal shift goes along with implementing multimodal travel passes (e.g. Sauter-Servaes and Nash, 2009), as well as public transport connections that can compete with air travel, at least within Europe, such as attractive night trains. However, instead of improving and harmonising the European railway network, it has been neglected in recent years, which has resulted in a reduction in quality (van Goevertden, 2007). Regulatory and pricing measures can only be effective if they are accompanied by structural changes, e.g., with regards to public transport, otherwise people will continue to use unsustainable modes, as long as they are still affordable.

Finally, making travel patterns subject to structural changes has failed so far probably also due to a lack of political commitment and hesitation in undertaking unpopular changes, such as accounting for

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the actual (environmental) costs of travel. Substantially intervening in travel and transport, especially long-distance travel, is still a taboo, which leads to unambitious and technology-oriented measures that lack substantial effects (Cohen et al., 2016).

5.6 Limitations of the study

Due to scientific and practical reasons, the scope of the study had to be narrowed down to some core questions. This led to desirable but also undesirable limitations with regards to the applied concepts, methods, and the thematic scope. Furthermore, limitations in terms of the generalisability of the obtained results have to be addressed.

Generalisation of results

The study applied case study research, which implies that the results were obtained within a given context. However, the inductive part of the study, which addresses the role of urban planning, produced a framework that can serve as a general framework for evaluating the role of urban planning; because it is not only based on empirical work, but to a large extent supported by findings from the literature; furthermore, because it is specifically designed to reflect the reality of diverse preconditions.

Furthermore, the selection of the cases, especially for the deductive part of the study, was guided by the principle to find ‘paradigmatic’ cases for urban and small town structure that could represent similar places in similar contexts.

Nevertheless, transferring the results as well as the implications for urban planning to other contexts should be done with caution with regards to specific aspects in the context of Northern Europe. Lifestyle and welfare level, which might be expressed in family-orientation, environmental awareness, car ownership or affordability of travelling, are essential conditions that might lead to different results in other parts of Europe or the world. Moreover, aspects such as planning traditions and established planning instruments, such as the Copenhagen Fingerplan as an example of a well-established planning instrument, may substantially affect the role of urban planning (see Pinho and Silva, 2015).

Conceptual aspects

Until now, the field of travel behaviour and urban structure has been addressed by a wide range of conceptual approaches, which are under continuous advancement and refinement. Therefore, gaining an overview of the state-of-the-art of research as well as, subsequently, selecting and linking the concepts that best serve the research objectives has proved to be particularly challenging. The study attempted to link different concepts of travel behaviour research in order to qualify the role of urban structure. The chosen approach may be discussed, while the results of the study suggest that some concepts that have been consciously excluded, such as the theory of planned behaviour, activity-based analyses or supplementary qualitative approaches (e.g., mobility biographies), may have the potential to fill some of the remaining explanatory gaps.
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Methodical aspects
In general, the selected methods are considered suitable for fulfilling the objectives of the study. The questionnaire-part of the study had to deal with some practical limitations. First of all, the sample size is considered sufficient, but is still limited and a higher number of respondents would have been desirable, e.g., with respect to the sensitivity of the statistical results. A further practical limitation concerns the fact that the questionnaire enquired ‘usual’ travel behaviour instead of the more commonly used ‘yesterday’s trips’, which may imply some bias. Finally, the overall study design entails limitations in terms of connecting the inductive and deductive parts of the study beyond a rather conceptual level due to the different cases used in each part.

Thematic aspects and scope
The study clearly illustrated the importance of a variety of factors that, besides urban structure, constitute travel behaviour. However, the study delivers limited results in terms of the extent and range of specific factors within the field of socio-economic and socio-demographic factors, lifestyles, preferences and attitudes. Furthermore, the study does not elaborate on the effect of specific features of urban structure (e.g., mix of functions, housing type) on travel behaviour. Although this was not intended as the objective of the study could be met by working with ‘paradigmatic’ types of urban structure (urban vs. peri-urban), developing some features in more detail would have been useful for deriving more specific recommendations for urban planning.

A frequent comment, e.g., during conference presentations, was owed to the fact that the study does not calculate differences in resource use, carbon impact or GHG emissions in relation to the different kinds of travel behaviour. Certainly, rating unsustainable behaviour would be very interesting and could be a possible extension of the study in order to assess ecological footprints. However, the objective was not to determine the extent of the environmental damage linked to certain behaviour, but to investigate options and paths for structural changes in order to shift travel behaviour in the direction of more sustainable patterns. After all, all kinds of carbon-intensive travel, whether it be by car or by plane, are harmful and they should not primarily be traded off against each other.

A final limitation concerns bridging science and policy-making for urban planning. Policy-making and planning can work more effectively when provided with results and knowledge derived from research in terms of facts, but also specific recommendations that preferably have been developed in cooperation between planning research and practice. This difficulty is, to some extent, reflected in the above discussion of the results; the implications and recommendations for urban planning and sustainable development that could be derived from the results have not yet been fully developed and require further examination.
6 Conclusions and perspectives for future research

6.1 Conclusions

The aim of this PhD study was to understand the relationship between urban structure and travel behaviour in order to evaluate practices and the capacity of urban planning for changing travel behaviour towards more sustainable patterns. The study responded to this aim by combining conceptual and empirical work that contributed to:

- Conceptualising the scope and key framing conditions for urban planning as defined by urban form/spatial structure, functional relations and policy context, especially with respect to transport planning.
- Examining the concept of urban structure with regards to transport energy use and travel behaviour, and outlining the potential, drawbacks and limitations of the influence of urban structure on travel behaviour.
- Reviewing and linking conceptual approaches for understanding travel behaviour.
- Investigating, empirically, the role of urban structure in daily modality styles as well as in weekend and holiday travel behaviour.
- Assessing compensation as a motivation for weekend trips and holidays among city dwellers.
- Elaborating urban structure and residential location as two analytically separate categories.
- Consequently, gaining a more comprehensive understanding of travel behaviour across different travel domains with respect to the influence of urban structure in relation to further determinants, such as socio-economic factors or lifestyle, reflected in residential location.
- Deriving implications and recommendations for urban planning to address travel behaviour by consolidating the findings on the role of urban structure.

With regards to the first research question, the study has illustrated by means of the reviewed literature and the empirical cases that urban structure can facilitate more sustainable travel patterns. Urban structural principles, such as high-quality density and compactness, including green spaces, mixed uses, and well-connected functions, are necessary preconditions for facilitating efficient transport energy use in cities. However, in existing urban areas, urban planning focuses on measures that are rather designed as complementing measures, such as public transport, or accompanying policies, such as parking restrictions, to optimise existing urban structure.

Travel exceeds the urban scope; accordingly, transport planning is a cross-border, cross-sectional and cross-level task and is, therefore, only to a certain extent within the scope of urban planning. Different travel domains (e.g., daily commute vs. weekend trips) exceed at different levels the scope and the territory of urban planning alone, which is also expressed by the three dimensions framing urban planning. But urban planning has an important role as partner in coordinated, cooperative and committed transport planning. However, sustainable urban development does require more than sustain-
able urban structure; it requires adding layers (policies), which involve higher tiers of planning and policy-making, which eventually affect individual behaviours, lifestyles and, thereby, travel patterns. Different travel domains underlie different drivers and, therefore, require different tailor-made policies and measures. Important conceptual categories of distinction, which are also relevant for policy making, include, e.g., bounded (commuting to work/education, dropping off and collecting children, shopping etc.) versus non-bounded trips (e.g., weekend trips).

In response to the second research question, the study has confirmed that urban structure (residential location) has an important influence on daily mode choices. However, weekend and holiday travel (frequency, transport mode) are apparently more closely related to lifestyle, stage of life, socio-economic factors and personal preferences, which are predominantly situated in urban or peri-urban settings (residential locations).

Answering the third research question, the results show that the respondents from Østerbro undertake more frequently weekend, holiday and plane trips than the respondents from Borup. Compensation as response to compact and dense urban living to some extent motivates more extensive leisure travel, which is expressed in weekend trips to summer cottages. Holidays and plane use, however, appear to be predominantly driven by lifestyle-related factors. Compared to other leisure or holiday travel, compensatory travel to summer cottages may, to a certain extent, be addressed by urban planning, which can make it more sustainable in some respects.

Consequently, residential location clearly plays a somewhat paradoxical role: For daily travel, the urban structure of a residential location exerts a relevant influence on travel behaviour. However, in terms of weekend/holiday travel, residential location presumably mainly acts as a proxy for certain lifestyles or people with certain socio-economic and socio-demographic characteristics. This has been illustrated by using two distinct spatial settings to assess travel behaviour. Hence, residential location and urban structure need to be treated as analytically separate categories, for which the concept of residential self-selection proved useful.

Sustainable transport planning demands that the different domains of travel (daily work and leisure, weekend, holidays, etc.) are specifically accounted for. In particular, all forms of non-bounded travel need to be given a more prominent position in transport planning and, hence, travel behaviour research. Leisure travel should not be restricted to the field of tourism research and planning as the underlying motives are linked to lifestyles, life plans, societal context, and daily life, which are directly linked to other domains of travel and also further areas of urban planning. Likewise, questions related to tourism are relevant for urban planning. Hence, urban planning, travel behaviour and tourism need to be more closely linked rather than addressed separately.

The case of Copenhagen, which is commonly considered a frontrunner in sustainable urban development, illustrates the shortcomings of transport planning. The city is often used as a ‘model’ of sustainable urban structure and is portrayed as the ideal of a ‘green city’ as it provides high-quality urban living. But a certain general level of affluence in a ‘cosmopolitan city’, cheap flights and ease of access
to an airport thwart the in other areas achieved sustainability accomplishments. People do not necessarily cycle every day because they have a green attitude or because it is cheap, they may do so because it is the most efficient transport mode (see City of Copenhagen, 2015). Similarly, their mode choices for weekend and holiday trips are most likely also driven by efficiency considerations, as the contradicting attitudes indicate. Additionally, it is important not to overlook any potential (indirect) rebound effects as these may represent part of the explanation for the observed travel behaviour among city dwellers, which has to be considered in policy-making.

Hence, besides designing tailor-made new policies, analysing the interface between urban structure and travel behaviour requires critically reviewing the policies that are currently in place, which may induce adverse effects (e.g. Boussauw and Vanoutrive, 2017; Holden and Linnerud, 2011). Moreover, many regulatory measures that are already in place or under consideration, such as emission trading schemes, carbon budgets or carbon compensation schemes for carbon-intensive transport modes, are not undisputed with regards to their effectiveness and actual impacts. They may offer the opportunity to buy one’s way out of reducing carbon-intensive consumption (see Borup, 2009), and, thereby, also increase social inequality with regards to transport mode choice and, thus, accessibility. Hence, more research and pilot studies on the impacts of comprehensive policy packages are needed.

‘Best practices’ of already achieved improvements in travel behaviour (e.g., Copenhagen having become a ‘cycling city’ again) may also provide inspiration for initiating paradigm shifts in other travel domains. Tackling certain domains of travel, such as long-distance, leisure or air travel, implies entering domains that are currently under some sort of taboo and, therefore, weakly regulated. However, looking back in time at daily travel shows that intervening is possible; regulating car use through road pricing or emission taxes seemed unthinkable a few decades ago.

To conclude, the potential for change through urban planning might be limited, but this should not be understood as an obstacle, but rather as an incentive to focus on its inherent competences and opportunities. This study is intended to appeal to the capacity and potential of urban planning, which have not been fully exploited yet. Urban planning has a crucial role to play in cooperating, enabling and engaging in the challenge of changing travel behaviour.

6.2 Perspectives for future research

Perspectives for future research emerge to some extent from the limitations of the study (see section 5.6). As mentioned above, it seems promising to address the same or similar research problems through the lens of concepts that have been consciously excluded, such as the theory of planned behaviour, mobility biographies or activity-space analyses, which could possibly provide additional insights and close some of the remaining explanatory gaps. Hence, conceptual work remains to be conducted in order to achieve a comprehensive understanding of travel behaviour in terms of its different domains as well as respective underlying determinants. Concepts will have to be further developed by incorporating new findings, contextual conditions and also developments such as global trends.
Conclusions and perspectives for future research

The conceptual perspectives are related to methodical perspectives. A study design that facilitates a more comprehensive integration of qualitative and quantitative methods by applying a mixed-methods strategy could improve mutual support in both parts and strengthen explanatory power. Suggestions include supplementing a questionnaire with travel diaries or respondents’ biographic information, or even conducting in-depth interviews with selected respondents. Moreover, repetitive or longitudinal application of a questionnaire appears promising to achieve results for the development of travel patterns over time, for instance, with regards to global trends. To the knowledge of the author, this has not been consistently covered yet by, for instance, national travel surveys – especially regarding weekend trips and holidays (see Christensen et al., 2014; Knudsen, 2014).

A particular topic that has only briefly been addressed in the analysis, due in part to a low number of positive responses of the respective survey question, concerns change in residential location (moving), which may contribute to the understanding and interpretation of travel behaviour. Moving combines several factors that have been identified as highly relevant, such as decisive factors behind residential choice (e.g., lifestyle, stage of life, preferences, and socio-economic factors) and the role of residential location in travel behaviour, e.g., to what extent incomers adapt to local modality styles or import their own. Furthermore, moving is a suitable indicator of personal budget restrictions, which are not only reflected in residential choices and mode choices, but are also related to overall trends such as changes in housing prices. Further topics that were addressed by the questionnaire survey, but that could not be adequately incorporated in this thesis due to delimitations in scope concern, firstly, a more detailed examination of car use with regards to trip purposes, patterns during the course of a week, and underlying motivations; and, secondly, more details on summer cottage use. Both topics promise for further insights into travel behaviour.

In terms of scope, the study has (apart from commuting) not covered business trips, which in a largely globalised world with its related business activities most likely account for a considerable share of environmental harm resulting from travel. Neither has the study included a profound discussion of tourism. Addressing business travel and discussing tourism as well as related trends is necessary and meaningful, not least in order to develop suitable and effective policies and measures when it comes to regulating travel.

The study claims to deliver results that are, to a certain extent, transferrable to similar contexts in Northern Europe and possibly the rest of Europe. However, some specific cultural aspects, such as summer cottage use, or structural conditions, such as planning systems or also welfare levels, raise the question of how representative the results would be in a wider application. Hence, it would be promising to include new case studies in Europe, but also to apply the study design to completely different types of cities in terms of their urban structure, such as less compact cities in the US or Australia.

Finally, in light of the obtained findings and the outlined perspectives, examining travel behaviour in relation to rebound effects and ecological footprint estimations with respect to different spatial settings and different travel domains is recommended and valuable, not least for policy-making.
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Paper I

Compact and Resource Efficient Cities? Synergies and Trade-offs in European Cities

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COMPACT AND RESOURCE EFFICIENT CITIES? SYNERGIES AND TRADE-OFFS IN EUROPEAN CITIES

Abstract. Cities are the main consumers of energy and resources but at the same time are considered as centres for innovation which can provide solutions to unsustainable development. An important concept regarding energy and resource efficiency on the scale of the city and city-region is the compact city. Compact cities and compact urban development are thought to decrease energy and resource demand per capita and increase efficiency. At the same time trade-offs and potential rebound effects of increased resource efficiency question certain achievements of a compact urban structure. This paper reviews aspects of resource and energy efficiency in compact city development in a European context. We conclude that, if the idea of the compact city should have any effect on resource and energy efficiency, accompanying measures have to be implemented, such as e.g. efficient public transport systems to offer alternative travel modes. Also the allocation of efficiency gains due to compact urban development has to be taken into account in order to avoid direct and indirect rebound effects.

Key words: compact city, resource use, spatial structure, urban form, energy efficiency.

1. INTRODUCTION

Transforming cities’ resource use to address the threats of climate change and resource scarcity is one of the main future challenges in urban development (Droge, 2011). Striving towards energy self-sufficiency, implementing regional resource cycles, retrofitting of the built environment as well as decoupling urban development and resource use are crucial for a city’s future vulnerability and resilience against changes in general resource availability. The challenge gets more complex as resource and energy efficiency in a city are deeply interwoven with other aspects of urban development, such as social structures as well as the geographical context (DG Regio, 2011).

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In Europe this is high on the political agenda through the Europe 2020 strategy (European Commission, 2010) and its priority of “Sustainable growth”, dealing with climate change and energy efficiency. As cities are the main consumer of energy and resources they are both problem and solution to tackle issues of efficiency and saving (Lewin, Hogain and Borghi, 2013). Furthermore, through innovation in green technologies and the removing of bottlenecks in network infrastructure, cities can enhance their competitiveness.

One widely used principle in sustainable urban development is the concept of the compact city. Compact cities are thought to decrease travel needs and increase resource efficiency due to shorter distances and higher densities. Different interrelations have been discussed in literature for several decades, both in conceptual and empirical studies. In this paper a short review of aspects related to resource efficiency and compact cities, including likewise potential drawbacks, is provided.

The compact city concept is applied in different forms – from the ‘original’ single-centred compact city to polycentric interpretations. These variations can be related to historical urban development, lifestyles, geographical context, city size, options to change urban form, as well as various specific development patterns taking place under the umbrella of global urbanization. In this paper we look at the compact city from a European perspective. Europe is characterized by predominantly polycentric settlement structures which attributes the city-region and the embedment of cities in a functional urban system (Nordregio et al., 2005).

2. DEFINING RESOURCE EFFICIENCY AND THE COMPACT CITY

As a framework for this review we define the terms ‘resource efficiency’ and ‘compact city’ as follows: Resource efficiency means the ratio of services generated from resources to resource input. It means “getting the most out of every unit you buy” (Herring, 2006 regarding energy efficiency). Thus, resource efficiency does not necessarily imply a reduction in resource consumption as long as the overall economic activity is still increasing. However, many policy-related uses of the term go further, including the sustainable use of resources or an absolute decoupling of resource use compared to economic growth (European Commission, 2011; UNEP, 2013).

The EU’s “Roadmap to a Resource Efficient Europe” (European Commission, 2011) considers the following resources: fossil fuels, material and minerals, water, air, land, soils, ecosystems/biodiversity, marine resources and waste. Some of these are in particular relevant in the context of a compact city discussion – especially regarding transportation, housing and infrastructure.
Regarding the use of resources it is important to include the city’s functional urban area, which means looking at the city-region rather than at the city alone. A city’s metabolism is deeply dependent on its urban-rural relationships and many resources which are used in the city are located or supplied in its surrounding region (e.g. water, land/soils, construction material, and possibilities for waste treatment). Furthermore many functional-dynamic relations as e.g. commuting are not limited to the core city but take place in a city’s functional urban area. These functional relations form the city-region and describe cross-scale interactions.

The compact city is a very illustrative term and concept. However, providing a general definition of a compact city is not an easy task. Compactness or density is a matter of scale. Built-up structures can be compact on the plot level, the neighbourhood or district level or also the city level. Compactness on one of these levels does not equal compactness on the other levels. Also, a densely built-up structure does not mean the city can necessarily make benefit out of that. Different resource types are more or less relevant on each of the levels. For instance, district heating works often on district scale, while transportation issues (e.g. commuting) are very much related to the compactness of the whole city or city-region.

This paper does not provide a review on the various understandings of a compact city, but mainly focuses on a recent publication of the OECD (2011). The report summarizes key elements to consider when planning for a compact city, reflecting the complexity of the concept (table 1), and emphasizing that the compact city is more than density. To get the compact city work as it is intended – facilitating to increase resource efficiency and reduce consumption – it is important to secure public spaces, a dense public transport system and a mixed land use on the local scale.

Table 1. Three key elements of compact cities (OECD, 2011, p. 15)

<table>
<thead>
<tr>
<th>Dense and contiguous development patterns</th>
<th>Urban areas linked by public transport systems</th>
<th>Accessibility to local services and jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban land is densely utilised</td>
<td>Effective use of urban land</td>
<td>Land use is mixed</td>
</tr>
<tr>
<td>Distinct border between urban and rural land use</td>
<td>Public transport systems facilitate mobility in urban areas</td>
<td>Most residents have access to local services either on foot or using public transport</td>
</tr>
<tr>
<td>Public spaces are secured</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this sense the compact city idea is not only translated into proximity but rather reflected in accessibility as well as mix of uses, which allows a more broad interpretation of the concept (Westerink et al., 2013). It even gets more
difficult when the definition should be empirically applicable, as very different urban forms can appear as compact cities. Furthermore, urban form needs to be adapted to the local geographical context as well as it is dependent on earlier development as e.g. existing transportation corridors. Also, polycentric urban development can fulfil the requirements for compact city development if it is realized as decentralised concentration (Anderson, Kanaroglou and Miller, 1996).

Finally, compact city development is not only an issue of resource efficiency but can have high impact on the social and economic development of a city and its neighbourhoods. Thus, there is no simple, empirically applicable definition of a compact city. However, this also allows many cities to work with the concept and adapt it to their own context and needs.

3. THE RELATIONSHIP OF SPATIAL STRUCTURE AND RESOURCE USE

Urban form and spatial structure are strongly related to resource use. The arrangement of land use directly affects energy consumption, primarily in the transport and space heating/cooling sectors (Owens, 1986). As Salat and Bourdic (2012, p. 1) state, urban form “constrains cities’ functioning (individual spatial behaviours, land use) and cities’ flows (travel, energy, water) and, retroactively, their functioning modifies both their morphology and their structure.” The enormous physical expansion of our cities in the last century and its implied problems especially regarding transport infrastructure and land consumption led to a renaissance of the compact city as an ideal in urban planning. The debate often distinguishes between “urban sprawl” versus the idealised “compact city” as two opposite urban forms (Schwarz, 2010). Compact and dense urban development is supposed to directly translate into lower energy use and carbon emissions per capita, less air and water pollution, and generally lower resource demands compared to less dense, less compact cities (Beatley, 2003). The key to a more efficient use of resources lies in the ‘heavy’ or intense use – in terms of build-up density and activity – of a limited area.

The main benefits of compact cities, which are broadly investigated in the academic literature, are related to efficient land use and limited travel needs (Williams, Burton and Jenks, 2004). Additionally, a compact or dense city structure provides remarkable benefits in the energy supply of a city, both regarding energy distribution and network as well as energy consumption, e.g. for heating or cooling (Williams, 2004).
There are also a lot of arguments put forward to support the idea of compactness going beyond the issue of resource use. This includes more generally the reduction of transaction costs, enabling e.g. social interaction and integration or the support of the creative economy (OECD, 2011).

However, the relationship of compact urban structure and energy efficiency comprises also controversies, which are described as the compact city dilemma (e.g. de Roo, 1998, 2000) and address the conflicts between “environmental intrusive activities” like noise and air pollution and environmentally sensitive functions like recreation (de Roo, 1998, p. 1030). We will get back to that in section 4. In the following we discuss three potential benefits of compact cities related to resource efficiency:

- Compact cities save land, e.g. agricultural area
- Compact cities save resource (energy) use for transportation, including
  - Save total transport needs (in km), and thereby reduce resource use for transport
  - Strengthen more resource efficient modes of transport, e.g. public transport
- Compact cities increase efficiency of infrastructure and reduce resource consumption, e.g. by enabling the use of district energy systems

In terms of resources (according to the above mentioned EU Roadmap), those three benefits relate mainly to the use of fossil fuels and land, to a lesser extent to material and minerals, water, air, land, soils, ecosystems/biodiversity, marine resources and waste, although, depending on the energy system (e.g. district heating from waste) some of those are also directly related.

3.1. Compact cities save land

The most obvious effect of compact cities is the reduced need of urban land. The general trend in Europe, as in the rest of the world (Angel, Parent, Civco, Blei and Potere, 2011), is still a progressing dispersion of urban land. Although population is concentrating in metropolitan areas, urban land in these areas is growing at proportionally higher rates. Between 1990 and 2006 Europe’s population grew by 7%, while the urban area in the same time grew by 37% (Fertner, 2012). Land is used less efficiently than before; we are consuming more and more land per capita. Although this is a general trend in Europe, the current land consumption per inhabitant can be very different between countries (Figure 1).
An important issue thereby is which kind of land gets urbanised. Cities are typically located in areas with the most fertile soils. Most areas getting converted to urban areas are agricultural land (European Environment Agency (EEA), 2006). Urban growth thereby directly affects urban-rural relationships as e.g. the local provision of food or resources. Higher densities of dwellings, jobs and other activities can reduce the (relative) need for new urban land. Decoupling of land consumption in relation to population or economic growth is a key issue. Furthermore, compact city development can reduce the fragmentation of the remaining areas, supporting more efficient agricultural practices, better connected nature areas and higher recreational potentials.

This process to achieve a compact city is described as ‘urban intensification’ by Williams et al. (1996), acknowledging the need for density and intensity of uses and activity likewise. Thus, intensification induces a sustainable management of
land (Williams, 2004). Urban regeneration (“recycling”) is a key strategy towards compact and intense urban development and sustainable land use when e.g. applied in the dispersed suburbs. It refers to regeneration of land that was previously developed (European Commission, 2012). However, more often we can see a reuse of urban land for a different urban function, e.g. former industrial areas which get converted to housing areas. This ‘brownfield development’, especially in the inner urban areas, is an essential element of sustainable management of urban space. Even more as it does not only minimize new land take, but also contributes to the revitalization of inner city zones and creates mixed use development. Germany, for instance, considers the development of the city centres as key instrument in city development strategies (“Flächenrecycling”). The average new land take of 117 ha per day between 1993 and 2008 shall be reduced by means of this strategy to 30 ha per day in 2020, which corresponds to a targeted share of 3:1 of central compared to decentralized development (Lieber and Preuß, 2010).

More efficient use of land can be caused by geographical limitations (e.g. cities in valleys or limited by water areas) but also by general policies on urban development. In the European context ambitions towards management of spatial development are present at all policy levels from the structural and territorial cohesion polices at EU level to the national, regional and local levels. The first urban growth management policies go back as far as to 1900 when the first green belts were designated (Ali, 2008), following the garden city movement as well as the preservation of green areas around major European cities (Konijnendijk, 2010). Today some variety of growth management is part of a ‘standard mode of operation’ in spatial planning. There are, however, large national and regional differences regarding competences, administrative delineations, systems and public interests between different parts of Europe. Although, the need to control urban sprawl is widely accepted (Nuissl and Couch, 2008; van den Berg, Braun and van der Meer, 2007), except for a few cities, sprawl stays a general challenge in Europe (European Environment Agency (EEA), 2006; Reckien and Karecha, 2008).

Building densities are not only related to land consumption, but also to general energy consumption. Theoretical calculations show clearly, everything else being equal, detached houses can require as much as three times the energy input of intermediate flats (OECD, 1995). Such a trend would imply generally higher net densities, thus, there are also implications for the urban scale. Regarding energy for transport and heating the following two sections present some evidence.

### 3.2. Compact cities save transport energy

Another main argument for compact cities is the reduction of energy use (especially fossil fuels) for transportation. Compact cities can reduce the average travel distance by supporting mixed used development in neighbourhoods allowing
short distances between different activities. Furthermore, compact cities also allow a more sustainable modal split, favouring “green” modes of transport. Highly attractive public transport systems as metro lines can only work efficiently in areas with a minimum density of attractions (households, jobs ...). So energy use is reduced through saving transport energy (by reducing length) and more efficient use (by using more energy efficient modes of transport).

Empirical studies show a correlation between urban form and transport behaviour. Newman and Kenworthy’s study from 1989 is the most well-known, showing a relation between population density in cities and gasoline consumption per capita (Newman and Kenworthy, 1989). The study got though criticized for methodological flaws. A main problem is the difficulty of comparing across different contexts and bounding conditions (Stead and Marshall, 2001). This includes the question if it is possible to control for preferences people have in their travel behaviour. For example, we could assume that a person who likes to bike also prefers to live in an area where this is possible (e.g. the inner city) and is more reluctant to move to more car-dependent areas than persons with other transport preferences. Furthermore it is difficult to separate effects caused by other factors, like socio-economic factors (especially income), which are difficult to consider comprehensively in a study, but might be more significant for transport behaviour than parameters of urban form (Echenique, Hargreaves, Mitchell and Namdeo, 2012). Another concern is if the right elements of the urban form are represented in empirical studies. For example available parking space is crucial for the choice of transport mode, but is seldom included in empirical studies. This however can make a considerable difference in older and newer compact urban developments.

However, other studies focusing on single cases or cases within similar context come up with similar conclusions as Newman and Kenworthy. Clark (2013) found that per capita vehicle distance, vehicle energy use and vehicle emissions are inverse to population density in metropolitan areas in the USA. Stead’s (2001) study from the UK shows that “socioeconomic characteristics typically explain around half of the variation in travel distance per person across different wards, whereas land-use characteristics often only explain up to one third of the variation in travel distance per person.” An in-depth study by Næss (2006) of the metropolitan region of Copenhagen showed, while controlling for many non-urban structure variables, that energy use for transport is higher for residents living further away from the centre than of those living close to or in the centre.

In another study, Næss and Jensen (2004) showed that urban structural variables influence travel behaviour, even in a small town of around 30 000 inhabitants. On the micro scale, the neighbourhood scale, Schwanen et al. (2002) showed that high population and employment densities are positively related to the use of public transport. On a global scale, most recent a study across
cultural contexts including a dataset of 274 cities (Creutzig, Baiocchi, Bierkandt, Pichler and Seto, 2015), shows that economic activity, transport costs, geographic factors, and urban form explain 37% of urban direct energy use and even 88% of urban transport energy use.

Finally it has to be considered that some of the discussed effects might decrease or even inverse when reaching a certain city size (Morrill, 1970). E.g. the advantage of proximity is decreasing the larger a (single-centred) compact city becomes. Capello and Camagni (2000) argue, with a perspective on economics, that at a certain urban size, diseconomies of scale apply as congestion effects take place, decreasing the efficiency of an urban location. Also, one of the main criticisms against addressing transport needs from an urban form perspective is the slow rate of change in the urban form, which allows significant changes in travel demands only in the long term (Williams, 2004).

3.3. Compact cities increase efficiency of infrastructure and reduce resource consumption

Besides saving land and transport energy, compact cities can also increase the efficiency of infrastructure in general (e.g. by the more intense use of infrastructure) and contribute a reduction of resource consumption (e.g. in infrastructure construction, where less meters of infrastructure is necessary to supply the same amount of users). Particular technical infrastructure needs a minimum density of activities/users, as for example high level public transport or district heating systems. However, infrastructure investment and maintenance costs per person might also be cheaper in compact cities. Conversely, the provision of infrastructure services in less dense or sprawled regions is comparatively expensive and less efficient.

Salat and Bourdic (2012) write that “a city four times denser consumes four times less land and sixteen times less network infrastructure.” They consider complex urban structures (e.g. redundancy in infrastructure networks) as structurally more efficient and resilient than simple ones. Compact city structures provide the necessary conditions to establish these complex urban structures. Higher densities also facilitate the implementation and introduction of sustainable technologies, like district heating (Williams, 2004, p. 45). Empirical evidence is however difficult to establish as there are many other factors influencing costs for infrastructure. Also, the increasing complexity of infrastructure development in densely built-up areas has to be considered, even though per capita resource use for construction and maintenance might still be lower than in less dense areas.

Spatial structure and urban form, like the general layout and orientation of buildings, have considerable influence on the heating and cooling demand of buildings. Futterer et al. (2013) found that compact urban development on neighbourhood/
building scale saves energy for heating and cooling in the single buildings, mainly through shading and insulation effects and influence on the micro climate. Næss (1997) names building types, local climate conditions and the grouping of buildings the most important spatial planning factors related to heating. Tereci et al. (2013) found that for a given urban site, compact, multi-family apartment blocks provide the lowest CO2 emissions per capita. However, they also found that shading, as a consequence of increased building density, can increase heating demand in heating dominated climates.

Large scale heating and cooling systems play an important role in several European countries. In the Scandinavian and Baltic States, district heating covers 40–60% of the heating demand (Connolly et al., 2014). Often operating with Combined-Heat-Power (CHP) plants, these systems are only feasible at particular minimum densities because of the infrastructure costs. Furthermore, because of energy transportation losses, the low-grade energy (e.g. heat) has to be produced relatively close to the end users. Also, efficient district heating/cooling systems need a mixed user structure, which both asks for low-grade energy (heat, hot water and steam) and electricity demand (OECD, 2011). This could be different kinds of industries, hospitals, hotels and residential areas, having not only different demands of the type of energy but also regarding the use pattern over the day, helping to smooth peaks of usage in the system. At the same time, district heating systems provide secure and efficient energy supply, with high flexibility in fuel use (e.g. Christensen and Jensen-Butler, 1982).

Regarding resource consumption, an important issue in district heating is the handling and conversion of energy. Introduction of CHP often is connected to a switch from high quality fuels to lower quality fuels, such as coal or biomass (OECD, 1995).

4. TRADING-OFFS AND REBOUND EFFECTS

There are a number of potential adverse effects of compact cities in environmental, social as well as economic terms (OECD, 2011; Westerink et al., 2013). These trade-offs regarding compact city development and resource use are not fully explored and subject to concrete planning measures because of their local complexity. They include:

– Potential negative effects on energy consumption, e.g. increase in energy consumption for cooling caused by urban heat island effects or inefficient energy use due to traffic congestion;

– Increased need of transportation and big infrastructure due to the reduced potential of on-site activities, e.g. farming on-site, waste treatment on-site, local water run-off, recreation on-site.
– High costs for infrastructure construction (e.g. underground metro instead of on surface).

Thus, the main problem is the definition of a compact city and that effects can be evaluated very differently depending on the applied scale. However, Næss (1997) concludes that there is, with goal-oriented and integrated planning, more complementarity than conflict between compact development on city (transport) level and on building (mainly heating) level.

Despite resource use there are other trade-offs with compact city development regarding social constraints. This includes housing affordability (Clark, 2013) but also issues related to quality of life, as traditional, local, environmental qualities. It can be questioned if it is possible to densify without destroying valuable nature or cultural heritage (Næss, 1997). Strategies that are often applied to deal with those “sustainability trade-offs” include urban renewal, limitations on car use, mixed land-use and life cycle residential strategies (Westerink et al., 2013). Also, there are some critiques of the idea that compact urban form really makes a difference. Other factors might be much more significant for resource use, e.g. the influence of the socio-economic factors on travel behaviour (Gordon and Richardson, 1997).

Looking at trade-offs from a broader perspective it is also important to consider rebound effects and how efficiency gains (e.g. in terms of money or time available for each citizen) through e.g. a higher use of public transport can actually effect (increasing) resource use in other sectors. For example, a study from Finland showed that people living in compact urban settings tend to have a high use of summer houses (Strandell and Hall, 2015). The lack of open space increases the need of people to travel further for recreational purposes. Similar ‘compensation effects’ have been observed in Sweden. Axelsson (2012) showed that in the bigger cities like Stockholm, the ecological footprint of transport activities is only half than in many other places. However, for other activities as recreation and culture, the average Stockholm has a much bigger ecological footprint than the average Swede. The impact of direct energy use (e.g. transport) is transferred to indirect energy use by consuming activities and products.

5. CONCLUDING PERSPECTIVES

Urban form and spatial structure is related to resource use, especially in regard to land use, transport energy and energy for heating/cooling. However, for a number of resources spatial structure and urban form play only a minor role. This includes especially consumption patterns related to lifestyle and economic wealth, like consumer goods use per person (including resource use for their production) or consumption of electricity for household appliances. Some resources might be indirectly connected
to urban form but are not further elaborated in this text. These include water use per person (might be connected to urban form and housing structure), and production of food. Compact urban development as e.g. in the form of urban growth management might ease the development pressure on agriculture and foster local production of food. However, dense urban structures can also complicate the cultivation of food in the city because of spatial limitations and shading effects.

Furthermore, urban density cannot be the only measure. If the idea of the compact city should have any effect on resource efficiency (and limit its trade-offs) other elements have to be implemented, as e.g. efficient public transport systems to offer alternative travel modes and cope with congestion.

This, however, does not mean we should not take action. Although and because the spatial structure of a city changes only very slowly, spatial planning has an important responsibility to avoid the risk of lock-in effects in the future. Buildings, communication and transport infrastructure as well as socio-technical systems have a long lifetime. Spatial planning can ensure a certain flexibility and farsightedness in urban development to be prepared for changes in the energy use (Naess, 1997). So, even though we implement behavioural measures (e.g. price incentives) which have immediate effect, the physical structures have to be included from the start, even if (or because) they cannot change that fast.

Regarding spatial planning principles, the example from Copenhagen (Naess, 2006) shows that to be energy-saving, sustainable and environmentally friendly, (1) most construction should be densification within existing urban area, (2) priority should be given to apartment buildings and terrace housing instead of detached single-family housing, (3) road and parking capacity should not be increased, but public transport strengthened and (4) densification should take place in areas already affected by technical infrastructure, to keep the urban green structure. To avoid potential trade-offs of compact city structures and to achieve the desired efficiency improvements, integrated, coordinated and tailor-made planning processes are necessary.

Finally, because of the different contexts cities are functioning in, it is important to see resource efficiency as a relative concept: that means not to be absolute efficient, but to become more efficient. In that regard it is very similar to how we work with the term sustainability. Still, even when we consider resource efficiency as a relative concept, eventually it needs to induce a decrease in the total resource and energy consumption in order to address the threats of climate change and resource scarcity. The allocation of efficiency gains has to be taken into account in order to avoid rebound effects. Indicators can play an important role to monitor progress when they also cover a temporal and systemic dimension to evaluate change.

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Paper II

Urban Structure, Energy and Planning: Findings from Three Cities in Sweden, Finland and Estonia

By Juliane Große, Christian Fertner, Niels Boje Groth

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Article

Urban Structure, Energy and Planning: Findings from Three Cities in Sweden, Finland and Estonia

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Abstract

Transforming energy use in cities to address the threats of climate change and resource scarcity is a major challenge in urban development. This study takes stock of the state of energy in urban policy and planning and reveals potentials of and constraints to energy-efficient urban development. The relationship between energy and urban structure provides a framework for discussing the role of urban planning to increase energy efficiency in cities by means of three in-depth case studies of medium-sized cities in Northern Europe: Eskilstuna in Sweden, Turku in Finland and Tartu in Estonia. In some ways these cities go ahead when it comes to their national climate and energy policies and aim to establish urban planning as an instrument to regulate and influence the city’s transition in a sustainable way. At the same time, the cities are constantly facing goal conflicts and limitations to their scope of action, which creates dilemmas in their strategic orientation and planning activities (e.g. regional enlargement and increased commuting vs. compact urban development). Finally, considering urban form and spatial structure along with the policy context as well as regional drivers and functional relations is suggested as a suitable approach for addressing the challenges of energy-efficient urban development.

Keywords

climate change; energy efficiency; Northern Europe; sustainable development; urban form; urban planning

Issue

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1. Introduction

In 2008, the European Union (EU) published the 2020 climate and energy package which contained three key objectives: a 20% reduction in EU greenhouse gas emissions from 1990 levels, an increase in the share of EU energy consumption produced from renewable resources to 20% and a 20% improvement in the EU’s energy efficiency. Following these “20-20-20 targets”, energy has been high on the agenda in urban development issues. Energy is an important element in many visions of future urban development, including sustainable and CO2-neutral cities, self-sufficiency, regeneration and resilience, but also in more general concepts such as a smart city (Girardet, 2015).

The first planning responses to climate change in urban areas date from the late-1980s/early-1990s. However, an analysis of urban climate change experiments revealed that they are mainly rather recent phenomena and showed that the experiments in Europe were predominantly conducted in the fields of the built environment, urban infrastructure (energy, waste, water) and transport, whereas urban form/planning, adaptation and carbon sequestration played only a minor role accounting for less than 25% of the experiments (Bulkeley & Castan Broto, 2013).

Recently, the proliferation of climate change experiments was reasserted by the European coopera-
tion movement Covenant of Mayors, whose signatory cities, almost 6,500 by 2015, voluntarily commit to meet and exceed the EU’s 20% CO₂-reduction target by 2020. Relevant examples of local initiatives (‘Benchmark of Excellence’) from the signatories show a focus on the public sector (municipal buildings, equipment/facilities, public lighting) as well as on local electricity production and transport (Covenant of Mayors, 2015), i.e. much in line with the findings of Bulkeley and Castán Broto (2013).

Hence, cities are already taking an active role in climate change policies. The interrelations between urban structure and energy are a key aspect of these urban climate policies. For decades, thus, development principles in urban planning for urban infrastructure and urban form were influenced by a concern for energy saving and efficiency. Related to these efforts concerning urban structure are initiatives to increase sustainable transport and the share of renewable sources in local energy generation, enhance energy efficiency in buildings, the use of combined-heat-power (CHP) generation and regional product cycles.

This study contributes to the scientific discussion of energy and urban structure by establishing a linkage between the known beneficial influence of urban structure to increase energy efficiency and the role of urban planning to affect urban structure purposefully. Starting point is that urban structure can facilitate efficient use of energy in cities. But, what we observe from the scientific literature and the case studies is that the possibilities of urban planning to influence or change urban structure are limited and that urban structure adapts only slowly to planning measures. However, optimising urban structure by complementing policies, such as the transport system or incentives, is crucial to influence travel behaviour. In our study we, thus, look for ‘complementing’ policies and aim to conceptualise the scope (fields of action) and key framing conditions (potentials and constraints) for municipal urban planning with an energy-efficiency agenda, especially in transport planning.

Section 2 provides a brief overview of the scientific literature focusing on the relationship between urban structure and energy use, which serves as a framework and ‘stepping stone’ for the empirical analysis. Section 3 summarises the applied empirical methods and introduces the multiple-case study of three Northern European cities: Eskilstuna in Sweden, Turku in Finland and Tartu in Estonia. The cases are separately investigated in sections 4–6; elaborating on the question, what role can cities—urban planning—play in increasing energy efficiency by working with urban structure? In section 7, we discuss the case study findings from the perspective of three interrelated dimensions of urban energy policy, which leads to the final conclusions in section 8.

2. Urban Structure and Energy—Providing a Framework

The relationship between urban structure and energy use in cities has been investigated by researchers for more than three decades and is being increasingly incorporated in policy-oriented documents from the EU and other institutions. Research ranges from studies which only focus on urban form-related aspects to broader approaches which also consider, for example, socio-economic factors.

This study uses the relationship between energy use and urban structure, with respect to its relevance for urban planning, as a framework for discussing the role of urban planning to increase energy efficiency by affecting urban structure. Urban structure itself is a disputed term. We focus on urban form and the transport system as we consider these to be two major components of urban structure when discussing energy efficiency.

2.1. Urban Form

One of the first in-depth studies to investigate urban structure and its implications for urban energy supply and consumption was conducted by Susan Owens (1986). Owens argues that energy supply, price and distribution shape urban and regional systems (spatial structure); but that in turn, the spatial structure (e.g. land use) determines energy demand and consumption (e.g. transport and district heating) and opportunities for alternative energy systems (feasibility). Owens identifies the energy-efficient characteristics of the spatial structure. The most influential characteristics are compactness, integration of land uses, clustering of trip ends and, at least to some degree, self-contained urban units of variable size and number. Owens describes the ‘compact city’, the ‘archipelago pattern’ and the ‘linear grid structure’ as the basic types of energy-efficient spatial structure.

An adaptation of the pure compact city concept is polycentric spatial structures (decentralised concentration) that appears to provide an answer to the trade-offs of a single compact city (e.g. disadvantages of high density) while keeping its advantages (Holden & Norland, 2005). Also, polycentric spatial structures provide an alternative spatial principle for regions where compact city development is hardly feasible (e.g. sparsely populated regions). Sparsely populated regions such as Estonia or Finland are characterised by dispersed urban settlements and long commuting distances. Polycentric urban regions, however, favour shorter commuting distances (Grunfelder, Nielsen, & Groth, 2015). A review of empirical studies from the Nordic countries (Naess, 2012, p. 41) also shows that “decentralized concentration may be the most energy-efficient settlement pattern at a wider regional scale”.

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In summary, dense and concentrated cities are considered to contribute reduce travel needs by car (Naess, Sandberg, & Røe, 1996). Newman and Kenworthy (1988) provide empirical evidence that locational factors have a greater impact on energy (fuel) consumption than congestion. Naess and Jensen (2004, p. 37) state that “urban structure makes up a set of incentives facilitating some kinds of travel behaviour and discouraging other types of travel behaviour” and, thus, the structural conditions have relevant potential to influence people’s travel behaviour (Naess, 2006). Compact urban structures and concentrated development facilitate and favour the efficient use of energy in cities (Fertner & Große, in press).

2.2. Transport System as a Complement to Urban Form

Studies on the interrelations between urban form and travel behaviour embrace a number of urban concepts ranging from the ‘compact city’ stressing “the merits of urban containment” (Breheny, 1995, p. 82) to ‘de-centralisation’ referring “to all forms of population and industrial growth taking place away from existing urban centres” (Breheny, 1995, p. 87). This definition of urban structure is related to the conceptualisation of cities in the regional context (e.g. Kunzmann, 2003) and stresses the importance of mobility as an integral part of the urban phenomenon: Urban form not only shapes mobility, mobility also shapes urban form. Mobility as an independent driver is revealed by a study by Rickaby and Steadman (1991) who show that differences in urban form between different compact city models do not have significant implications for energy use in transport; only competitive public transport systems and accompanying policies could induce reductions in energy use. Also Naess (2006) recognises the need to complement transport reducing urban planning with accompanying instruments to achieve significant changes. Likewise, public transport needs to be accompanied by land use and transport planning to restrict car use and direct development towards transit nodes (Anderson, Kanaroglou, & Miller, 1996).

Therefore, it is difficult to clearly verify the relationship between urban structure and travel behaviour. Some critics even consider it as ‘weak’ or ‘uncertain’, also due to the importance of socio-economic factors and people’s attitudes (Naess & Jensen, 2004). Breheny (1995), for instance, considers the present high mobility levels as a relevant obstacle to inducing significant changes in travel patterns through changes in urban form. Certainly, socio-economic factors influence the effectiveness of energy efficient urban structures, such as actual travel patterns. But the consideration of socio-economic factors implies also the potential to carry out customised and, thereby, effective energy policies (Stead & Marshall, 2001; Stead, Williams, & Titheridge, 2004).

2.3. Energy and Urban Structure

Despite uncertainties, the literature persistently reveals that energy consumption corresponds with urban structure (e.g. Naess, 2006; Newman & Kenworthy, 1988). Accordingly, principles of urban development, notably urban structure, are crucial for energy efficiency. Consequently, policies on urban structure are preferable as an energy conservation strategy. However, tapping the full potential of these policies requires knowledge on how to optimise urban structure by accompanying policies (e.g. transport planning) since functional relations (e.g. transport system, mobility) and policy context (e.g. efficiency of local and national policies) are essential complements in order to constitute energy savings.

The literature, though, provides evidence that the implementation of energy efficiency policies is often limited by the policy context. This frames the potential and constraints for urban planning to affect and facilitate the development of energy efficient urban structure—and is also the issue we particularly look into by means of the case studies.

2.4. The Planning System, National and Local Policies as Complements

In energy planning, a particular role is accorded to municipalities. Brandoni and Polonara (2012) see the importance of municipal energy planning processes especially in identifying the crucial aspects in energy consumption as well as assessing the most suitable energy-saving initiatives and identifying renewable sources that can be more properly exploited in a given local area. Williams (1999), however, questions the power of the (local) planning system to ensure urban ‘intensification’ and manage its consequences. Williams considers the process of policy implementation as responsible for the divergence between theory and planning practice. Local policy making takes place within policy regulations from higher tiers of government that determine the range of local options (van Stigt, Driessen, & Spit, 2013). Additionally, the prerequisite of administrative boundaries induces a problem whenever functional relations exceed these boundaries. Thus, decision-making in line with the established government levels is insufficient in, for instance, transport policies since transport widely exceeds administrative boundaries while responsibility for action is likewise contested (Marsden & Rye 2010). A case study of the Gothenburg Metropolitan Area (Lundqvist, 2015) illustrates how the jurisdictional fragmentation of a metropolitan area counteracts the coordination of planning processes and that coordination which is built on administrative boundaries is not sufficient to achieve climate change adaptation.

However, according to Bulkeley and Betsill (2005), solutions remain tied to the local level instead of exceeding the local frame due to the neglect of interac-
tions of economic, social and political processes across different governance levels and systems as well as gaps in cooperation at the regional level and among constituent municipalities (Geerlings & Stead, 2003). Furthermore, Brandoni and Polonara (2012) consider coordination at the regional level as fundamental to enable municipalities to concentrate their efforts on their agenda.

To conclude, ambitious and purposeful municipal energy planning requires, on the one hand, policy-wise backup from the national level and, on the other hand, coordination at the regional level. This implies examining governance structures and their influence on urban form in more depth to identify and establish “helpful governance structures” (Schwarz 2010, p. 44).

3. Methods and Introduction to the Cases

The empirical core of this study is conducted as in-depth, multiple-case study (Yin, 2014) of three Northern European cities, which were part of the European project PLEEC—“Planning for Energy Efficient Cities” (Kullman et al., 2016): Eskilstuna in Sweden, Turku in Finland and Tartu in Estonia (see Figure 1). The selected cases are all medium-sized cities (see Table 1), which function as regional centres and each is striving to increase its energy efficiency. In some respects, the cases are therefore representative of medium-sized cities in Europe. They also face similar challenges such as urban sprawl and regional commuting, which are related to their urban structure and their position within the regional urban system. At the same time, the cities are faced with similar potential and constraints to addressing urban structure and increasing their energy efficiency. This supports the intention of this paper to draw some transferable conclusions by using “analogous generalization”, which Neergaard (2007, p. 271) defines as the extrapolation of a researched insight (role of urban planning in the three case cities) to new contexts (other medium-sized cities in Europe).

As we look at the role of urban planning in influencing urban structure and energy efficiency, it was important for the choice of the cases that the role of municipal planning in the planning system of each country was comparable. The countries’ planning systems are to a certain extent similar as the main competences in spatial planning are allotted to the municipal level, whereas planning on the regional level is rather weak (COMMIN Project Co-ordination, Academy for Spatial Research and Planning, 2015; Smas & Fredricsson, 2015). Also in terms of their planning culture and style—based on a general classification of major traditions of spatial planning in Europe (European Commission, 1997)—all three countries adopt the comprehensive integrated approach, while Sweden also shows elements of the regional economic approach (ESPON, 2007). The comprehensive integrated approach is described as ‘framework management’ with a “very systematic hierarchy of plans from national to local level” (European Commission, 1997, pp. 36-37). The regional economic approach is characterised by wide social and economic objectives (European Commission, 1997). Accordingly,
the level of comprehensiveness differs between the three countries; Finland and Estonia show both vertical and horizontal coordination, whereas the Swedish planning system shows mainly horizontal and only weak vertical coordination (ESPON, 2007).

The investigation of the cases is based on the review of related scientific publications and national, regional and local planning documents, as well as field visits and interviews with civil servants and stakeholders in urban development and energy planning in each city.

The reviewed planning documents (see Appendix I) comprise current local planning documents (and selective previous versions or drafts) that address issues of spatial development, transport, climate and energy planning. Planning documents of superordinate levels (regional, national) were included if relevant for local planning.

The fieldwork was conducted between March and June 2014 as part of the EU-FP7 project PLEEC. The interviews were semi-structured; the interviewees were asked about their perception of framing conditions and national energy regulations, the evolution of spatial planning, current transport planning as well as national and local energy policy and the role of regional planning. One to three individuals from the respective department or institution (see Appendix II) participated in each interview. All interviews were recorded and transcribed. The interview transcripts were coded manually or with the assistance of software by using keywords (e.g. “compact”, “commuting”, “land use”) and split into analytical categories (e.g. urban structure, municipal planning, cooperation) (Further information can be found in Fertner, Christensen, Große, & Hietaranta, 2015; Große, Groth, Fertner, Tam, & Alev, 2015; Groth, Große, & Fertner, 2014).

For each case, we provide an overview of status and practice of urban form and transport. Consequently, we discuss potentials of and constraints on urban planning, while also addressing factors for success such as scope of action, local power relations and leading principles as the baseline for municipal actions to integrate energy issues in urban development.

The effort required to reach their 2020-target for GHG emissions reduction varies according to each city’s current baseline: Turku and Tartu need to reduce their annual GHG emissions on average by about 10,000 tons CO₂-equivalent each year, whereas Eskilstuna only needs to reduce by less than 4,000 tons CO₂-equivalent each year (see Table 1).

At first glance, the figures in Table 1 suggest a negative correlation between population density and energy consumption. Tartu shows the highest density and by far the lowest energy consumption per capita, whereas Eskilstuna and Turku show lower densities of the urban area but significantly higher energy consumption per capita. However, a closer look at the figures reveals that other factors, e.g. purchasing power standards per capita (PPS) or car ownership, which is considerably lower in Tartu, also appear to be relevant.

Figure 1 and Table 1 also reveal the differences between the administrative boundaries and the actual urban area of the cities. While the total area of Eskilstuna municipality is much larger than just its urban area, the urban area of Turku significantly exceeds its municipal boundary. In Tartu, the municipal boundary corresponds more or less to the urban area, but signs that it is exceeding its boundaries are already visible.

By means of the case studies, we investigate the
question, what role can cities—urban planning—play in increasing energy efficiency by working with urban structure? In particular, we look at the role of urban planning, and its potential and possible constraints to facilitating the development of energy-efficient urban structure.

4. Energy and Planning in Eskilstuna

The Swedish municipality of Eskilstuna, with almost 100,000 inhabitants in 2013 (Eurostat, 2014) and a size of 1,250 km², is located about 100 km west of Stockholm and is within Stockholm’s commuter belt. Eskilstuna is situated in the county of Södermanland, which is part of the Stockholm-Mälaren Region, a polycentric region with about 3 million inhabitants. Eskilstuna marks a former major industrial location in Sweden; since the 1970s, its population has been rather stable at between 90,000 and almost 100,000 inhabitants. Deindustrialisation in the 1970s caused a pronounced decline in the number of jobs, making the city ripe for urban restructuring.

4.1. Urban Form and Transport

Urban densification and connectivity to transport routes facilitated by public transport are generally acknowledged as two main principles of energy-efficient urban development in Eskilstuna. With the current Comprehensive Plan (Översiktsplan 2030, Municipality of Eskilstuna, 2013b), a radical decision was made to abandon the former settlement planning in the attractive coastal area of lake Mälaren (see Figure 2). Furthermore, future urban development will be concentrated within or close to the existing urban cores as well as in connection with public transport links between these cores (Figure 2). Currently, two thirds of the inhabitants live within 3 km of Eskilstuna city centre.

However, with few exemptions, transportation depends on fossil fuels. The design of effective incentives to reduce fossil fuels remains the key challenge, also at the national level. The main transport mode for commuting—as far as to Stockholm—is the private car (Municipality of Eskilstuna, 2012, p. 6).

A key observation in this regard is that energy efficiency policies in Eskilstuna have been developed subordinate to the basic drivers of economic development. Regional enlargement and the chance to enter Stockholm’s labour market offered the municipality a way out of a long economic downturn, which lasted from the mid-1970s to the late 1990s, but is also facilitated by increased commuting.

4.2. Potential of and Constraints on Urban Planning—Factors of Success

The main legislative foundations for municipal urban planning are the Planning and Building Act, the Swedish Environmental Code and Sweden’s 16 environmental quality objectives (Swedish Environmental Protection Agency, 2013). The latest Planning and Building Act from 2011 gave the municipal Comprehensive Plan a stronger strategic role so that it became

![Figure 2](image-url). Development concept of Eskilstuna Comprehensive Plan emphasising urban development in the core of Eskilstuna City and along selected transport axes. Source: Municipality of Eskilstuna, 2013b).
a key instrument of sustainable development. The Comprehensive Plan applies a broader perspective including topics such as economic development, regional aspects of transportation and water supply. The core planning documents, Comprehensive Plan, Climate Plan and Transport Plan (Municipality of Eskilstuna, 2012, 2013a, 2013b), as well as the interviews provide evidence that energy efficiency has become an almost omnipresent issue, integrated across sectors and between levels in the municipal organisation.

However, energy and climate policy is carried out in the following two policy arenas in Eskilstuna, which is also emphasised by different planning documents: the municipality acting as a concern (‘planning’) and the municipality acting as a stakeholder of energy initiatives (‘strategy’) (Municipality of Eskilstuna, 2013a). The concern is in charge of all decisions regarding municipal planning, services and infrastructure. The municipal climate plans and projects are carried out with a high level of effectiveness by the Eskilstuna municipal concern (municipal services, energy supply, public enterprises, e.g. Eskilstuna Energi & Miljö AB), due to omnipresent ‘sustainability thinking’. This is also supported by an annual ranking of all Swedish municipalities in regards to their climate ambitions and plans in which Eskilstuna achieved top positions (MiljöAktuell, 2015).

The more comprehensive climate strategies that include energy initiatives outside the municipal concern have, however, much greater potential regarding, e.g. CO₂-emission reductions. The concern’s share of potential CO₂-emission reductions accounts for only 7% of the city’s total. However, the development and implementation of such comprehensive strategies relies on the establishment of partnerships between the municipality and, e.g. private companies, organisations and the public, which operate outside the direct influence of the municipality.

Thus, although the municipal area of Eskilstuna corresponds to its urban region, which provides a much larger territorial scope than in Tartu or Turku, the distinction between the two policy arenas is very relevant for the operational preparation of plans, projects and strategies as well as their final practical effectiveness. Furthermore, particularly in regional transport planning, the municipality depends on the National Traffic Authority due to its responsibility for investments in regional transport networks, whereas the municipality can regulate local public transport by contracting the public transport operators.

However, policies of energy efficiency remain ‘second-order’ compared to the economically driven ‘first-order’ development of the regional urban system that comes along with increased transport. The development of the regional urban system with its orientation towards Stockholm’s labour market is not questioned by the city authorities; it is taken as a starting point for policies that aim to compensate the effects of commuting such as policies to enhance commuting by train rather than car and the development of a dense urban structure in hub-and-spoke patterns adjacent to public transport lines.

Thus, although the Transport Plan (Municipality of Eskilstuna, 2012) and the Climate Plan (Municipality of Eskilstuna, 2013a) contain measures for sustainable transport, these remain “mild answers to strong trends”. This twofold planning strategy—first, matching trends in the outside world and second, setting up hierarchies of sustainability visions (strategy) and goals (plans and projects)—is a major constraint on urban planning in Eskilstuna.

5. Energy and Planning in Tartu

Tartu is the second largest city in Estonia with 98,000 inhabitants (2014) and a municipal area of roughly 40 km². The city is located about 180 km southeast of the capital Tallinn. Tartu has no relevant big industries; the main employers are the municipality (incl. hospital) and the university.

5.1. Urban Form and Transport

Estonia is characterised by a generally low population density with only a few dispersed urban centres. The National Spatial Plan (NSP) “Estonia 2030+” (Ministry of the Interior, 2013) implemented a concept called “Low-density urbanised space”, which combines the concept of sustainable (compact) urban space with the low-density settlement characteristics of Estonia. The concept aims to match people’s daily activity spaces by applying a polycentric spatial strategy, which is supposed to favour shorter commuting distances (Grunfelder et al., 2015; Ministry of the Interior, 2013). The concept is also adopted in the previous and current Master Plan of Tartu (City of Tartu, 2006).

Although the core city is rather compact, Tartu is facing ongoing urban sprawl and car-dependent commuting from the surrounding suburbs as well as long distance commuting, e.g. to the capital Tallinn, which provides diverse employment opportunities. The modal split shows significant differences between journeys within Tartu and journeys between Tartu and its surroundings. While the former shows a high share

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1 Interview with Eskilstuna Municipality, Town Planning Department, Planavdelningen (översiktsplanerare), comprehensive planning, 07.05.2014.
2 Interview with Eskilstuna Municipality, Town Planning Department, Planavdelningen (trafikplanerare), Transport and bicycle plan, 08.05.2014.
3 Interview with City of Tartu, Department of Urban Planning, Land Survey and Use, city planner, planning documents and comprehensive planning, 05.06.2014.
of public transport and walking, the latter involves a high share of car use, especially for work-related journeys. A strong driver for this development is a continuous increase in the number of registered cars in Tartu towards European levels of car ownership (Eurostat, 2014; Tartu City Government, 2011).

5.2. Potential of and Constraints on Urban Planning — Factors of Success

The outlined challenges of regional commuting and urban sprawl require coordinated cross-municipal efforts at the regional level. The Estonian planning system delegates the main responsibility for planning to the 215 municipalities. In the case of Tartu, this implies that the municipality’s planning competences are limited to the core city area and do not cover the urban region. This is also reflected in the city’s planning documents such as the Master Plan and the Transport Development Plan as they are limited to the municipal boundaries. Similarly, demands for regional positioning and integrated planning within the functional urban area as mentioned in, e.g. the Development Strategy “Tartu 2030” (Tartu City Government, 2006) can be hardly addressed.

However, planning at the regional level (county) is rather weak in Estonia (Rooste, Kull, Gauk, & Tali, 2013). Addressing problems that exceed the city scale requires voluntary cooperation between municipalities to, e.g. connect the surrounding settlements by a bus service. But as the municipalities’ interests reasonably exceed their municipal borders and may be in conflict, such as the assignment of residential areas in the urban fringe, suburban areas develop dispersed and contradicting.

Regulating urban sprawl requires coordinated action by Tartu and its surrounding municipalities as, both, city planning documents assign new residential areas on the outskirts of the city (City of Tartu, 2006); and zoning for suburban housing in the five surrounding municipalities of Tartu significantly exceeds real demand (Gauk & Roose, 2011). Roose et al. (2013) consider the local governments’ lack of experience in land use planning as one reason for urban sprawl.

A planned reform to merge local governments (municipalities) to form geographically and demographically logical entities with a minimum of 5,000 inhabitants may be an opportunity to improve regional and cross-border coordination. The reform, which is supposed to be implemented in 2017, also emphasises the need for cooperation at the county level. Furthermore, a new county plan, the intention of which is to apply a more comprehensive perspective, is currently being developed and is supposed to be approved in late 2016 or early 2017.4

A further constraint on municipal energy planning in Estonia concerns a different national commitment to energy efficiency or sustainability than for example in Sweden. In Estonia, energy production is responsible for the highest share of emissions. Estonia is highly dependent on oil and gas imports and more than 90% of its electricity production is based on oil shale (Rudi, 2010). In order to achieve the GHG-reduction target for 2020, the main challenge for Estonia lies in reducing this high share of oil shale, which is responsible for almost 70% of GHG emissions from the energy sector (Roos, Soosaar, Volkova, & Streimikene, 2012). At the same time, local oil shale and peat resources are considered an important replacement for imported resources. Thus, although regional energy production and increasing the share of renewable and local fuels are generally considered relevant measures, national efforts to achieve greater energy efficiency are driven by an ambition to decrease fuel dependency (e.g. Russian gas) and secure energy supply rather than sustainability objectives (Ministry of the Interior, 2013).


Turku is the centre of the region of Southwest Finland with a population of about 180,000 inhabitants (2014) in the municipality and 316,000 inhabitants in the urban region. The city is situated on the southwest coast of Finland about 150 km west of Helsinki. It is an important university city with about 40,000 resident students.

Since industrialisation, Turku has also been an important industrial centre. Today, after considerable restructuring of the industrial sector, 79% of the jobs in the city are in the service sector. However, the region still has a significant industrial sector (Hanell & Neubauer, 2005). Approximately a third of the 150,000 jobs in Turku’s urban region are located in the centre of the city.

6.1. Urban Form and Transport

The traditional low-density settlement structure in Finland represents a key challenge. Like Estonia, urban settlements are dispersed and long commuting distances are usual.

Turku has experienced extensive urban growth since the 1950s. While the municipality of Turku has been stagnating since the 1970s, the city region has continued to grow resulting in a large urban area with a dispersed settlement structure on the fringe. In recent decades, sustainable urban development has been actively promoted and the city region has densified, albeit with several growth centres at the regional scale.

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4 Interview with City of Tartu, Department of Urban Planning, Land Survey and Use, city planner, planning documents and comprehensive planning, 05.06.2014; see also haldusre-


5 Interview with Fortum Tartu, Management board and development management, 06.06.2014.
(Vasanen, 2009). Thus, like many other Finnish cities, Turku is urbanising, but is experiencing urban sprawl at the same time, which is inducing regional and car-dependent commuting to as far as Helsinki. This urbanisation trend needs to be taken as a chance towards more energy-efficient urban structures.

According to a study of 240 European cities, Turku is in the group of cities which “are characterised by a higher number of patches, a lower compactness index of the largest patch and a higher area of discontinuous urban fabric” (Schwarz, 2010, p. 41). This kind of urban structure generally implies a greater need for transportation (Clark, 2013; Naess, 2006) and, therefore, increased energy use for transportation.

The case of Turku exemplifies the importance of a regional dimension in terms of urban structure⁶, which is at odds with a focus on the local level, particularly in Finland with its comprehensive local self-government and participatory planning (Hentila & Soudunsaari, 2008). Regional coordination is, therefore, dependent on voluntary collaboration between municipalities. An example of regional coordination for urban development is the “Regional structural model 2035” (City of Turku, 2012), which was set up by Turku and 13 neighbouring municipalities as a common land-use strategy. The Structural model 2035 aims to establish common objectives for all significant land-use activities and focuses on more compact urban development along public transport corridors.

The ‘Regional development and commuting structure’ map (‘Yössökäytäntöalueen aluerakenne ja seudullinen kehitys’) depicts different centres (see Figure 3), proposing—despite the strong urban core—a polycentric structure. Densification takes place at the regional scale with several growth centres. The challenge for Turku is to connect growth policies, such as attraction of population and industries, with energy efficiency policies.

6 Interview with City of Turku, Climate, Environmental Policy and Sustainable Development, City Development Group, City Administration, 24.03.2014.

Figure 3. Regional structural model 2035. Source: City of Turku, 2012.

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instrument to primarily provide the “judicial legitimation for development decisions made elsewhere” (Mäntysalo, 1999, p. 179).

The Regional structural model 2035 shows that even though the city of Turku aims to limit urban sprawl and focus on developing the central areas (the aim is 80% of the growth within the core), the fragmented municipal structure around Turku represents a major constraint because the surrounding municipalities simply have other interests than pursuing this strategy of densification. Furthermore, for practitioners, energy is, in general, of less interest compared to other planning-related topics. This is also obvious in Turku’s “Resource wisdom roadmap”, the follow-up programme to the “Climate and Environment Programme 2009–2013” (City of Turku, 2009), which explicitly focuses on economic growth, but intends to combine this with the climate and environmental goals under the headline of ‘green growth’.

7 Discussion: Urban Planning towards Energy Efficiency—Addressing Three Dimensions

The literature provides evidence that specific characteristics of urban form promote energy efficiency, but this does not constitute savings or generate specific energy consumption patterns. Increasing energy efficiency requires complementing urban form by accompanying policies, such as organisation of the transport system, which is also illustrated by the case studies.

The cases illustrate the options for and limitations to urban development regarding increasing energy efficiency. In all three cases, a major challenge is to address regional, especially car-dependent commuting, which is a consequence of urban sprawl and regional enlargement, in order to connect with more distant labour markets; also, to prevent further sprawl and stimulate compact and concentrated development of the urban core. An essential similarity and framing condition for the role of urban planning in all three cities is that the main spatial planning competences are allocated to the municipal level, whereas the regional level is rather weak. However, the territorial scope—municipal area compared to respective urban region—differs considerably.

Consequently, in all three cases the urban planning strategy is to focus rather on complementing and optimising the given urban structure by considering those functional relations as well as the policy context than substantially altering urban form, which is not only a difficult but also a long-lasting procedure.

Therefore, based on the knowledge from the scientific literature and the findings from the case studies, we can position urban planning as acting with and within the interrelated dimensions of urban form/spatial structure, functional relations and policy context (see Figure 4). Functional relations includes all kinds of urban flows and interactions between the physical urban areas such as the transportation and energy system as well as a city’s position in the regional urban system. The policy context includes the relevant organising principles such as the planning system, the local power relations and national and local energy policy.  

![Urban Form/ Spatial Structure Diagram](image)

**Figure 4.** Urban form/spatial structure, functional relations and policy context as interrelated dimensions.
Energy and climate planning is characterised by the interplay of these dimensions; they determine the potentials of and constraints on urban planning and comprise fields of action of urban energy planning.

7.1. Urban Form and Policy Context

All three case studies illustrate how a municipality’s scope of action is determined by the policy context:

- through the allocation of planning competences to the national, regional and local level;
- the territorial scope of a municipality, as defined by the municipal boundaries or
- the policy arena in which energy and climate policy is carried out (e.g. coverage of a municipal concern as in Eskilstuna).

The differences between the three cases regarding their municipal area in relation to their actual urban area exemplify the interrelation between urban form and policy context. Eskilstuna municipality comprises its urban region and municipal planning can address urban form in relation to the core urban area and the surrounding regional urban system. Turku and Tartu municipality, however, hardly comprise their urban area. Moreover, municipal planning is bound to the municipal concern. Eskilstuna exemplifies how these boundaries can be purposively adopted in plans of the municipal concern and strategies that are carried out with stakeholders in the entire municipality but outside the municipal concern.

However, strong planning competencies at the local level combined with an urban area that stretches beyond the administrative boundaries, as in Tartu and Turku, constrain municipal planning and imply challenges for coordination at the regional level. Development tasks that exceed municipal borders have to be addressed on a voluntary basis by municipalities.

Consequently, the options for and constraints on urban energy planning are further framed by local power relations—the interplay between municipal planning competences, the involvement of stakeholders as well as coordination between neighbouring municipalities and regional planning bodies. Although these relations are not discussed in-depth in the case studies, their importance is obvious as exemplified by Eskilstuna municipality acting as a stakeholder of energy initiatives that relies upon partnerships, as well as by voluntary regional cooperation as a necessary strategy in Turku and Tartu.

7.2. Urban Form and Functional Relations

The way people travel is not sufficiently explained by the characteristics of urban form. This is confirmed by the case studies, which show that travel patterns are strongly influenced by the position of a city in the regional urban system and the distribution of labour markets. Eskilstuna, for instance, is a small and compact city, which facilitates environmentally friendly transport modes such as public busses or cycling; but the functional relations—regional commuting to Stockholm—go far beyond its urban area. Obviously, functional relations do not necessarily correspond to spatial structure; the high and increasing mobility levels have initiated an ongoing detachment of mobility from the city boundaries (Breheny, 1995). In all three cases, problems of regional and long-distance commuting confirm that energy efficient urban development is not just about ‘urban containment,’ but is increasingly related to the wider regional urban system. However, the outlined challenges are particularly at odds with the scope of energy policies in Tartu and Turku, which is framed by extensive municipal self-government in combination with restrictive administrative boundaries.

7.3. Functional Relations and Policy Context

Constraints on addressing energy efficiency in urban development may also originate in contradictory leading principles in national or local policies as well as the need to react to trends in the outside world.

The case of Tartu illustrates that the level of commitment to sustainability or the driver behind energy efficiency (e.g. decrease fuel dependency) in national or urban policies determines both the content and the total effect of established objectives and measures—either energy efficiency is a subordinate or a leading principle. Also Jørgensen and Årø (2007) attest the state a still strong role in urban policy (‘national urban policy’). Solving urban problems at the local level requires backing from the state, but the state requires strong stakeholders at the local level in order to conceive and implement its urban policy (Uitermark, 2005).

In the case of Eskilstuna, the problem is not a lack of commitment to sustainability, but a twofold strategy in urban policies, following first-order economically driven policies and downgrading energy efficiency as a second-order policy. This strategy is partly a reaction to trends from the outside world, but this order of priority is also taken for granted and its negative effects are compensated by second-order ‘sustainability’ policies. Moreover, regional transport planning as compensation policy depends on the National Traffic Authority in Sweden, which constrains efficiency policies even more.

Both cases provide examples of policy trade-offs that originate from goal conflicts, either due to subordinate commitment to energy efficiency or ambiguities in the development strategy. The cases also reveal common discrepancies between functional relations and policy context.

The outlined interrelations between the dimensions of urban form/spatial structure, functional relations
and policy context disclose potential areas where to put complementing policies, e.g. organisation of the transport system, purposefully in place to complement urban structure.

8. Conclusion

The aim of this paper is to examine the role cities can play in increasing energy efficiency. The relationship between urban structure and energy use provides a suitable framework for discussing the potential of and constraints on urban planning to increase energy efficiency.

Research provides evidence that compact urban structures and concentrated development facilitate efficient energy use. However, urban structure must not only be viewed from an urban form perspective, but should include considerations of functional relations and the policy context. Thus, urban planning has to act with and within these dimensions.

For example, mobility is a phenomenon that is not sufficiently explained by urban form, but underlies further conditions. Transport patterns are interwoven with land-use, distribution of functions and the positioning of a city in the regional urban system. In terms of sustainable transport, cities encounter their limitations at their borders. Municipal transport planning addresses inner city transport. Increasing (energy intensive) mobility beyond municipal boundaries emphasises, however, the relevance of regional transport planning.

The case studies illustrate that cities have a lot of potential with regards to addressing climate change; but there are quite different possibilities for action, including voluntary cooperation, improved institutionalised regional plans, or even ‘soft’ regional strategies on climate and energy, which may be important as a benchmarking instrument. Moreover, creative use of available tools and instruments as well as providing space for innovative initiatives implies significant potential, but requires concerted interplay between these efforts by engaging the relevant actors and steering by the municipality.

Urban planning can play an influential role, but a major crux lies in acknowledging, enabling and promoting innovations as well as necessary partnerships and cooperation involving stakeholders, local and regional authorities and private actors for long-term strategic policy making and implementation. Besides a (planning) system backing up such strategies, political commitment to sustainable energy development and entrepreneurial spirit of the relevant stakeholders play a crucial role; something the three investigated cities, despite challenges due to the administrative structure, seem to be good examples of.

Acknowledgements

We would like to thank all our PLEEC co-workers in the case studies who do not appear as co-authors in this paper. In addition, we are grateful to the civil servants and stakeholders that participated in the research project. The research was partly conducted in the frame of the project PLEEC (Planning for energy efficient cities), GA no. 314704, www.pleecproject.eu, funded by the European Commission’s 7th Framework Programme.

Conflicts of interests

The authors declare that there is no conflict of interest.

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Appendix I. Reviewed planning documents.

<table>
<thead>
<tr>
<th>Location</th>
<th>Document Title and Details</th>
</tr>
</thead>
</table>
| **Eskilstuna** | Eskilstuna kommun, 2005, Översiktsplan and Fördjupad Översiktsplan för Mälarstrand 2005 (comprehensive plan)  
Eskilstuna kommun, 2013, Översiktsplan 2030. Antagen av kommunfullmäktige 2013-08-29 (comprehensive plan, application draft)  
Eskilstuna kommun, 2013, Klimatplan för Eskilstuna (climate plan)  
Länsstyrelsen Södermanlands län, 2012, Klimat- och Energistrategi för Södermanlands Län. Länsstyrelsen Södermanlands län, Nyköping  
Regeringskansliet, 2014, The Swedish Energy System |
| **Tartu** | City of Tartu, 1999, Master plan of Tartu 2012 (Tartu linna üldplaneering aastani 2012)  
Tartu City Government, 2006, Development Strategy Tartu 2030  
City of Tartu, 2006, Master plan of Tartu (Tartu linna üldplaneering)  
Tartu City Government, 2011, Tartu City Transport Development Plan 2012-2020  
City of Tartu, 2015, Action Plan for Sustainable Energy Management 2015-2020 for the City of Tartu (draft)  
Ministry of the Environment, 2007, Estonian Environmental Strategy 2030  
Ministry of the Interior, 2013, National Spatial Plan Estonia 2030+ |
| **Turku** | City of Turku, 2009, Climate and Environment Programme 2009-2013  
City of Turku, planned for 2015, Resource wisdom roadmap 2040  
City of Turku, 2001, General Plan for Turku 2020  
City of Turku, 2012, Master Plan for Turku 2035  
City of Turku, planned for 2017, General Plan for Turku 2029  
City of Turku, 2010, Transport Plan for Turku  
City-region of Turku, 2012, Regional Structural Model 2035  
Southwest Finland, 2014, Southwest Finland Regional Strategy 2035+ (Programme for 2014-17)  
Southwest Finland, 2014, Southwest Finland Transport Strategy 2035+  
Ministry of Employment and the Economy, 2014, Energy and Climate Roadmap 2050  
Appendix II. List of interviews.

**Eskilstuna, 7/8th May 2014**
Eskilstuna Municipality, Town Planning Department, Planavdelningen (översiktsplanerare), Comprehensive Plan, 1,5 h
Eskilstuna Municipality, Cultural Heritage, Culture and Leisure Department, Arkiv och muséer (arkivarie), history of Eskilstuna, 1 h
Eskilstuna Municipality, Municipal Board, Kommunledningskontoret (project manager), Climate Plan, 1 h
Eskilstuna Municipality, Town Planning Department, Planavdelningen/Trafikavdelningen (trafikplanerare), Transport and Bicycle Plan, new parking norms, 2,5 h
Eskilstuna Energi & Miljö AB, district heating, 1,5 h
Eskilstuna Energi & Miljö AB, water and sewage water, 1 h
WSP Environmental, building certification, Eskilstuna indoor swimming hall and arena, 1,5 h

**Tartu, 5/6th June 2014**
City of Tartu, Department of Urban Planning, Land Survey and Use, city engineer, energy and transport planning, 1,5 h
City of Tartu, Department of Urban Planning, Land Survey and Use, city planner, planning documents and comprehensive planning, 1 h
City of Tartu, Department of Municipal Property, 1 h
Fortum Tartu, Management board and development management, energy supply, 1,5 h

**Turku, 24/25th March 2014**
City of Turku, Climate, Environmental Policy and Sustainable Development, City Development Group, City Administration, Development Manager, general urban development, 1,5 h
City of Turku, Urban Planning/Environmental Division, City Planning Architect, urban planning and Skanssi project, 1,5 h
City of Turku, Urban Planning/Environmental Division, Traffic & Transportation office, transport planning, 1 h
Regional Council of Southwest Finland, Natural resource planner, regional planning and development, 1 h
Oy Turku Energia - Åbo Energi AB, Development manager, energy production and supply, district heating, electricity grid, 1 h
Paper III

Linking daily travel behaviour with weekend and holiday travel: Exploring the role of modality styles and urban structure in Greater Copenhagen

By Juliane Große, Anton Stahl Olafsson, Trine Agervig Carstensen, Christian Fertner

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Linking daily travel behaviour with weekend and holiday travel: Exploring the role of modality styles and urban structure in Greater Copenhagen

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Abstract

In the course of climate change and sustainable development, changing travel behaviour marks a cornerstone towards reducing the negative impacts of CO₂-emissions and resource exploitation. The differences in daily travel (e.g., commute to work) between urban and peri-urban areas have been comprehensively researched. However, other travel domains (e.g., weekend trips and holidays) have only recently received more attention; despite their environmental impact.

In order to establish a more comprehensive understanding of the role of urban structure and other explanatory factors in travel behaviour, we apply an integrated analysis across different travel domains. We investigate if and how daily travel patterns (modality styles) correspond with weekend/holiday travel behaviour.

The study is based on a questionnaire survey, which was conducted in an urban district in central Copenhagen and a small town in the commuter belt of Greater Copenhagen in spring 2016. First, we identify ‘modality styles’ by applying clustering techniques based on people’s daily mode choices. Second, we relate the identified modality styles to socio-economic and socio-demographic factors, weekend/holiday travel behaviour, and attitudes.

The results reveal that the urban structure of a residential location (e.g., urban vs. peri-urban) influences the constitution of predominant daily modality styles. We found, furthermore, a tendency for more weekend and holiday trips among the urban sample; we interpret this as interdependency between modality style, residential location, car ownership/use, and plane use expressed in certain travel behaviour.

Keywords: air travel, long-distance travel, mobility styles, spatial structure, transport modes, urban form
1 Introduction

Previous research has established the importance of urban structure for travel behaviour. Urban settings are associated with short distances due to compact spatial structures and mixed uses that facilitate reduced travel demand and more sustainable mode choices. In contrast, peri-urban or rural areas are supposed to encourage less sustainable travel behaviour (e.g. Ewing and Cervero, 2010; Fertner and Große, 2016; Næss, 2012; Nielsen et al., 2013). Hence, urban structure defines “exogenous baseline conditions provided for travel choice”, but “socioeconomic and demographic characteristics provide the individual/household setting in which travel choices are finally made” (Silva et al., 2015, p. 24). Although recent research has increasingly incorporated such factors, we still have insufficient knowledge on the link between travel behaviour and drivers beyond urban structure, such as socioeconomic factors, residential preferences, lifestyle, or attitudes (Silva et al., 2015).

Research on travel behaviour used to predominantly focus on shorter daily travel (Kristensen et al., 2014) or travel as a matter of routine (Vilholmson, 2007). Only recently has leisure travel, particularly occasional long-distance travel, received more attention; this is highly recommended, considering its extent and environmental impact. In the more wealthy Western European countries, long-distance travel (≥ 100 km) accounts for probably almost 50% of greenhouse gas emissions from travel (van Goeverden et al., 2016). Moreover, international tourism is steadily increasing, having reached 640 million arrivals by plane in 2015 (World Tourism Organization, 2016).

Understanding travel primarily as a matter of routine entails that, firstly, certain travel domains related to many types of (occasional) leisure activity (e.g., weekend trips or holidays) remain, despite their considerable share, yet widely disregarded; additionally, important characteristics and drivers of leisure travel – typically more flexible in time and place (Vilholmson, 2007) – likewise remain understudied.

The explanatory factors that underlie travel behaviour, such as urban structure, socio-economic factors, residential preferences, lifestyle, or attitudes are interrelated but have different significance in different domains of travel (e.g. van Acker et al., 2010). Accordingly, the paper aims to explore the role of urban structure and other explanatory factors in travel behaviour across different travel domains, including daily travel and weekend/holiday travel, in order to gain a more comprehensive understanding. Consequently, we aim to challenge the widely understood divide between urban versus peri-urban travel patterns (conceptualised as ‘modality styles’) when weekend trips (max. 3 nights) and holidays (more than 3 nights) are included in the analysis.

We investigate if and how daily modality styles correspond with weekend/holiday travel behaviour in order to, subsequently, critically reflect on the role of urban structure and potential further factors (socio-economic and socio-demographic factors, attitudes) in constituting travel behaviour.
2 Modality styles and residential self-selection as linked concepts

The concept of mobility styles facilitates relating travel behaviour to socio-economic characteristics and moreover to lifestyles, personal preferences or attitudes in order to identify patterns of travel behaviour (Barr and Prillwitz, 2012; Krueger et al., 2016). Departing from the idea of market segmentation or customer classification (Diana and Mokhtarian, 2009), the concept is used for segmenting a population in homogenous groups with similar attributes that are considered relevant for explaining travel behaviour and supports, furthermore, relating travel patterns to different spatial settings (Barr and Prillwitz, 2012).

Mobility styles are applied in varied ways, as regards the included travel domains and the studied attributes for identifying patterns of travel behaviour. Commonly used attributes for grouping individuals are socio-economic factors (e.g. Ryley, 2006), attitudes or values (e.g. Anable, 2005; Barr and Prillwitz, 2012; Jensen, 1999; Krueger et al., 2016; Ohnmacht et al., 2009; Prillwitz and Barr, 2011; Pronello and Camusso, 2011), actual travel behaviour (e.g. Prillwitz and Barr, 2011), or a combination of the aforementioned (e.g. Julsrud, 2014; Klinger et al., 2013; Lanzendorf, 2002).

Some studies have utilised the concept of mobility styles for investigating leisure travel, either solely or related to other types of travel: The results of a German study suggest that mobility styles in weekend leisure travel largely explain distances travelled by car, and that car ownership and preferences for car use for leisure travel turn out as mutually reinforcing factors (Lanzendorf, 2002). A Norwegian study (Julsrud, 2014) identified mobility types, based on daily travel behaviour and socio-demographic factors, that show significant differences regarding number, travel mode and purpose of trips abroad and long-distance trips (>100 km) (Julsrud, 2014). A study from the UK applied a novel approach by comparing two segmentations, one based on daily travel patterns and a second one based on travel-related attitudes and environmental values. This revealed discrepancies between attitudes and reported holiday travel behaviour (Prillwitz and Barr, 2011). Further studies have shown deviations between travel-related attitudes and actual leisure travel behaviour (e.g. Böhler et al., 2006; Holden, 2007); hence, attitudes are a useful parameter to qualify self-reported behaviour.

For the present study we limit the applied approach to modality styles that are considered here as an expression of mobility styles (Olaåsson et al., 2016; Vij et al., 2013). Modality styles can be understood as “behavioral predispositions, characterized by a certain travel mode or set of travel modes that an individual habitually uses” (Vij et al., 2013, p. 165).

We aim to specifically reflect on the role of urban structure across different travel domains; i.e. how modality styles are represented in different spatial settings (urban vs. peri-urban) as well as how links are maintained or offset when weekend trips/holidays are included in the analysis.

Therefore, we consider residential self-selection in our framework. The concept of self-selection assumes that people choose their residential location based on their attitudes and preferences (van Ackert et al., 2010), particularly with regards to travel needs, abilities, attitudes, and preferences (Bohle et al., 2009; de Vos and Witlox, 2016; van Wee, 2009). A German study combined the concepts of mobility cultures1 and residential self-selection to investigate changes in travel behaviour (transport modes choices) after moving (Klinger and Lanzendorf, 2016). The study found that car use is very much tied to urban form and accessibility at the local level, as well as income, age, and employment, whereas cycling and walking are strongly influenced by bicycle- or walking-oriented cultural settings. Public transport use is supported by both a transit-oriented cultural setting and respective transport policies.

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1 Mobility cultures can be understood as an extension of the actor-oriented concept of mobility styles, they additionally comprise the spatial, social and political elements and dynamics of mobility (Delfner et al., 2006; Klinger et al., 2013).
Considering residential self-selection proves useful for distinguishing the influence of the urban structure of a residential location on travel behaviour from the influence of other factors (e.g., socio-economic factors or lifestyles) that might simply be expressed in residential choices and, hence, ‘disguised’ as residential location.

3 Methods and data

The paper is based on data from a questionnaire survey carried out in May and June 2016 in Østerbro (Copenhagen municipality) and Borup (Køge municipality, both Denmark).

The chosen analytical approach was inspired by the work of Prillwitz and Barr (2011) and Julsrud (2014). We segmented the respondents of the two case areas, based on self-reported daily mode choices (work and free time), and related the identified modality styles to socio-economic and socio-demographic parameters, weekend and holiday travel behaviour, and travel-related attitudes.

3.1 Study cases

Østerbro is an inner district of Copenhagen with about 76,800 inhabitants in March 2016 (Københavns Kommune, 2016) and an area of 8.74 km². Borup is a small town with about 4,600 inhabitants in 2016 (Statistics Denmark, 2016) and an area of 2.6 km². Borup is located about 55 km southwest of central Copenhagen and thereby in daily commuting distance (by car or public transport) to Copenhagen as well as to Roskilde, the second largest city on Zealand with a distance of about 20 km north of Borup (see Figure 1).

![Map of case areas](image)

Figure 1: Map of case areas (data source: Kort 10, Danish Agency for Data Supply and Efficiency)

The dense urban district of Østerbro and the small town of Borup were chosen to highlight the spatial component of the analysis, as they represent two very distinct types of living environment in terms of urban structure. Integrating them into one study allows for direct comparisons between travel patterns of urban and peri-urban residents, which is a core contribution of this study.
3.2 Sampling method (survey)

The questionnaire survey was carried out as an online survey; given an internet penetration rate of 94% in 2016 in Denmark (European Commission, Eurostat, 2016) and the age target group (18-65 years), this was judged as an appropriate method.

In Østerbro the questionnaire was distributed via e-mail to 757 households using an online panel provider. The response rate of completed surveys was 31.7%. Each household in Borup, except housing for elderly people and nursing homes, received a written invitation with a link to the online questionnaire (1,874 households in total). The response rate of completed surveys was 9.3%. We placed additional advertisements in the local newspaper, library, and supermarkets to promote and access the survey.

The questionnaire had to be answered by one person per household, aged between 18 and 65 years, to focus on the working population; respondents outside this age group were included if they were part of the working population. The final sample consisted of 239 complete responses in Østerbro and 157 in Borup. Furthermore, we included 23 partially complete responses in Østerbro and 20 in Borup in the final sample, totalling 439 responses.

The Borup sample deviated slightly from the town’s age structure with an overrepresentation of respondents between 45-64 years. The Østerbro sample deviated from the district’s age and gender structure (underrepresentation of younger and overrepresentation of older population, overrepresentation of women). Gender distribution was therefore excluded from the analysis.

3.3 Variables and statistical analysis

Table 1 summarises the variables used for the statistical analysis. For designing the questions, we considered previous studies on travel behaviour and nationwide statistics such as The Danish National Travel Survey (Christiansen and Skougaard, 2015) and Statistics Denmark. Other than commonly applied in travel surveys, people were asked about their 'usual' behaviour (related to the last 12 months) to avoid seasonal bias as the sampling period was limited to spring 2016.
<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grouping ‘modality styles’</td>
<td>Primary (combined(^2)) transport mode to work/education</td>
<td>categorical (single choice)</td>
</tr>
<tr>
<td></td>
<td>Multiple transport mode(s) to get to daily life free-time activities</td>
<td>categorical (multiple choice)</td>
</tr>
<tr>
<td>Group differences</td>
<td>Location before moving (if moved within the last 5 years)</td>
<td>urban/non-urban</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>years (continuous)</td>
</tr>
<tr>
<td></td>
<td>Highest completed level of education</td>
<td>ordinal</td>
</tr>
<tr>
<td></td>
<td>Household size (total no. of adults and children)</td>
<td>ordinal</td>
</tr>
<tr>
<td></td>
<td>Income (Danish kroner) per person per household (incl. adults and children)</td>
<td>Logarithm</td>
</tr>
<tr>
<td></td>
<td>Distance (in km) to workplace or place of education</td>
<td>Logarithm</td>
</tr>
<tr>
<td></td>
<td>Number of cars per household</td>
<td>ordinal</td>
</tr>
<tr>
<td></td>
<td>Number of weekend trips (max. 3 nights) in Denmark/Skåne, outside Denmark/Skåne(^3) within the last 12 months</td>
<td>ordinal (categorical frequency per destination)</td>
</tr>
<tr>
<td></td>
<td>Number of holiday trips (more than 3 nights) on Zealand, elsewhere in Denmark, elsewhere in Scandinavia, elsewhere in Europe, outside Europe, total within the last 12 months</td>
<td>ordinal (categorical frequency per destination)</td>
</tr>
<tr>
<td></td>
<td>Transport mode(^4) to last weekend trip (max. 3 nights) in Denmark/Skåne, outside Denmark/Skåne</td>
<td>categorical</td>
</tr>
<tr>
<td></td>
<td>Frequency of different transport modes (car, ferry, train/bus, plane, other) to holiday trips (more than 3 nights) within the last 12 months</td>
<td>ordinal (categorical frequency per transport mode)</td>
</tr>
<tr>
<td></td>
<td>Total number of private plane trips within the last 12 months</td>
<td>ordinal (categorical frequency)</td>
</tr>
<tr>
<td></td>
<td>Statements on travel-related attitudes [1 - agree ... 3 - disagree]</td>
<td>3-point Likert scale</td>
</tr>
</tbody>
</table>

Table 1: Variables used in statistical analysis

We applied descriptive statistics for an initial characterisation of the studied variables. The main statistical analysis consisted of two steps: (1) grouping the survey responses in modality styles, and (2) comparing the modality style groups in terms of their characteristics (identifying group differences).

The grouping of the respondents in modality styles (see Table 1) was based on the respondents’ primary transport mode to work/education (cycling, car, public transport, other) and the transport mode(s) to get to free-time activities in daily life (walking, cycling, car, public transport). We only considered responses that had valid values for both transport mode to work and free-time activities; totalling 339 responses.

For an initial assessment of a purposeful grouping, we conducted agglomerative hierarchical clustering with Ward’s method and squared Euclidian distance, a commonly used approach in hierarchical clustering (Mooi and Sarstedt, 2010), using IBM SPSS Statistics 24. Due to the limitations of hierarchical clustering when using binary variables, we also applied SPSS’ TwoStep clustering as an alternative procedure (Schendera, 2010), using the same variables as for the hierarchical clustering. Departing from the grouping suggested by the hierarchical and the TwoStep clustering, we conducted the

\(^2\) The respondents were asked to select the different transport modes they combine in one journey. Thus, ‘primary transport mode to work’ includes also combined modes; in these cases the predominant mode was considered as primary mode (e.g., bicycle and public transport: public transport is primary).

\(^3\) Skåne (English: Scania) is the southernmost county of Sweden, which can be considered as part of the Greater Copenhagen Region based on distance.

\(^4\) Primary transport mode if multiple modes were combined (e.g., public transport and plane: plane is primary).
final grouping of the respondents manually as this allowed minimising the outliers and accurate distinction by mode choices.

Subsequently, we compared the modality styles created in the clustering process to identify significant group differences for a set of parameters (see Table 1). To account for the spatial dimension of the sample, we additionally split the two mixed clusters into the (a) Østerbro and (b) Borup sub-samples (hereafter referred to as 2a/3a for Østerbro and 2b/3b for Borup) and also explored the group differences for this extended grouping. The tables in the following sections summarise the most meaningful results, the complete results are included in the supplementary material at the end of the paper.

For the group differences, we applied Pearson’s Chi-square test with post-hoc pairwise comparisons using the z-test of two proportions with a Bonferroni correction for categorical data (Laerd Statistics, 2016), and Kruskal-Wallis H with post-hoc pairwise comparisons using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons for ordinal and continuous data (Laerd Statistics, 2015); the statistical tests were conducted in IBM SPSS Statistics 24 and XLSTAT 2017.

The assumption of independence of observations was met as each respondent can only belong to one modality style group, and the respondents are further unrelated as only one person in each household answered the questionnaire.

4 Results
4.1 Daily travel behaviour (modality styles)

The hierarchical clustering suggested five meaningful clusters of modality styles. The TwoStep procedure identified similar clusters; however, it also extracted a high number (108) of outliers. The final manual grouping of the respondents is composed of four modality styles (see Table 2):

- Cluster 1 – Committed cyclists use the bicycle both to commute to work and in their free time (additionally, other transport modes in free time);
- Cluster 2 – Public transport users (work) use public transport to commute to work, but a mix of transport modes for getting to free-time activities;
- Cluster 3 – Non-public transport users use a mix of modes but never public transport, neither to work nor to free-time activities;
- Cluster 4 – ‘Die-hard’ car drivers\(^6\) exclusively use the car both to commute to work and in their free time.

Only few outliers (14) that do not belong to any of the four clusters remained; the outliers were excluded from the analysis of group differences.

\(^6\) Term based on Anable (2005)
Table 2: Deduction of manually grouped modality styles based on hierarchical and TwoStep clustering

Table 3 provides an overview of the four modality styles and how they are represented in Østerbro and Borup. Cluster 1 (*committed cyclists*) is almost 97%-represented in Østerbro, and cluster 4 (*‘die-hard’ car drivers*) is represented by more than 76% in Borup; clusters 2 and 3, in contrast, share a mix of respondents from both case areas.

| Hierarchical clustering | Committed cyclists | ‘Die-hard’ car drivers | Public-transport-users only to work | General public-transport-users | Non-public-transport-users | /-
|-------------------------|-------------------|------------------------|------------------------------------|-------------------------------|----------------------------|-----
| **TwoStep clustering**  | Committed cyclists | ‘Die-hard’ car drivers | Public-transport-users to work / free time cycling | Public-transport-users to work / free time car | Outliers (108) | /-
| **Manual clustering**   | Committed cyclists | ‘Die-hard’ car drivers | Public transport users (work) | Non-public transport users | Outliers (14) | /-

<table>
<thead>
<tr>
<th></th>
<th>Cluster 1 - Committed cyclists</th>
<th>Cluster 2 - Public transport users (work)</th>
<th>Cluster 3 - Non-public transport users</th>
<th>Cluster 4 - ‘Die-hard’ car drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N in each cluster</td>
<td>96</td>
<td>110</td>
<td>64</td>
<td>55</td>
</tr>
<tr>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Primary transport mode to work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work / stay at home</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Walking</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Cycling</td>
<td>96</td>
<td>100.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Car</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Public transport</td>
<td>0</td>
<td>0.0%</td>
<td>110</td>
<td>100.0%</td>
</tr>
<tr>
<td>Other*</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Multiple transport modes to free-time activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>11</td>
<td>11.5%</td>
<td>36</td>
<td>32.7%</td>
</tr>
<tr>
<td>Cycling</td>
<td>96</td>
<td>100.0%</td>
<td>54</td>
<td>49.1%</td>
</tr>
<tr>
<td>Car</td>
<td>5</td>
<td>5.2%</td>
<td>38</td>
<td>34.5%</td>
</tr>
<tr>
<td>Public transport</td>
<td>12</td>
<td>12.5%</td>
<td>33</td>
<td>30.0%</td>
</tr>
<tr>
<td>Other**</td>
<td>1</td>
<td>1.0%</td>
<td>3</td>
<td>2.7%</td>
</tr>
<tr>
<td>Residential location</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Østerbro</td>
<td>93</td>
<td>96.9%</td>
<td>53</td>
<td>48.2%</td>
</tr>
<tr>
<td>Borup</td>
<td>3</td>
<td>3.1%</td>
<td>57</td>
<td>51.8%</td>
</tr>
</tbody>
</table>

* *) non-distinctive or rare combinations of walking, cycling, motorbike, car and plane
**) e.g., motorbike, carpool, plane

Table 3: Identified daily modality styles

4.2 Socio-economic and socio-demographic group differences

The socio-economic and socio-demographic differences between the groups are particularly expressed when accounting for the residential location (see Table 4). Cluster 1 shows the significantly highest education level, in particular compared to clusters 2a, 2b, and 3b. We found no significant group differences for household size or income between the four modality styles. However, accounting for residential location revealed that households in Borup are comparatively bigger (number of children), and correspondingly with lower income per person. The public transport users – Borup (2b) have the lowest income and the biggest household size.
<table>
<thead>
<tr>
<th></th>
<th>1 Committed cyclists</th>
<th>2 Public transport users (work)</th>
<th>3 Non-public transport users</th>
<th>4 'Die-hard' car drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N in each cluster</td>
<td>96</td>
<td>53</td>
<td>57</td>
<td>28</td>
</tr>
<tr>
<td>Education level*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.0$^a$</td>
<td>3.0$^a$</td>
<td>3.0$^a$</td>
<td>3.0$^a$</td>
</tr>
<tr>
<td>N</td>
<td>93</td>
<td>51</td>
<td>56</td>
<td>27</td>
</tr>
<tr>
<td>Mean rank</td>
<td>183.919</td>
<td>143.157</td>
<td>138.429</td>
<td>146.870</td>
</tr>
<tr>
<td>Household size*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>2.0$^b$</td>
<td>2.0$^b$</td>
<td>3.0$^c$</td>
<td>2.0$^b$</td>
</tr>
<tr>
<td>N</td>
<td>87</td>
<td>48</td>
<td>55</td>
<td>26</td>
</tr>
<tr>
<td>Mean rank</td>
<td>138.264</td>
<td>123.896</td>
<td>193.655</td>
<td>129.577</td>
</tr>
<tr>
<td>Ln income / person*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>73</td>
<td>41</td>
<td>51</td>
<td>24</td>
</tr>
<tr>
<td>Mean rank</td>
<td>140.575</td>
<td>143.451</td>
<td>104.324</td>
<td>166.167</td>
</tr>
<tr>
<td>No. of cars per household*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>0.0$^a$</td>
<td>1.0$^a$</td>
<td>1.0$^a$</td>
<td>2.0$^b$</td>
</tr>
<tr>
<td>N</td>
<td>96</td>
<td>110</td>
<td>207.172</td>
<td>64</td>
</tr>
<tr>
<td>Mean rank</td>
<td>117.531</td>
<td>140.595</td>
<td>207.172</td>
<td>235.773</td>
</tr>
<tr>
<td>Ln work distance*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>1.792$^a$</td>
<td>3.219$^a$</td>
<td>2.996$^a$</td>
<td>3.555$^a$</td>
</tr>
<tr>
<td>N</td>
<td>96</td>
<td>108</td>
<td>62</td>
<td>55</td>
</tr>
<tr>
<td>Mean rank</td>
<td>80.130</td>
<td>202.278</td>
<td>160.516</td>
<td>221.645</td>
</tr>
<tr>
<td>Location before moving*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>22$^a$</td>
<td>18$^b$</td>
<td>58.1%</td>
<td>4$^c$</td>
</tr>
<tr>
<td>Non-urban</td>
<td>3</td>
<td>12.0%</td>
<td>41.9%</td>
<td>17</td>
</tr>
</tbody>
</table>

*) significant group differences (p<0.05)  
$^{ab,c}$ different superscript letters denote significant group differences

Table 4: Socio-economic and socio-demographic group differences

The distribution of **number of cars per households** is as the modality styles would suggest: Clusters 1 and 2 have significantly fewer cars than clusters 3 and 4. This is overlain by a significant difference in car ownership between Østerbro and Borup, i.e. clusters 1 and 2a have significantly fewer cars than clusters 2b, 3a, 3b, and 4. Interestingly, the number of cars among the **public transport users – Østerbro** (2a) is even lower than among the **committed cyclists** (1).

The **distances to workplace** relate directly to modality styles: **Committed cyclists** have the shortest median distance (ln=1.79) compared to **‘die-hard’ car drivers** with the longest (ln=3.56). Obviously, distance to workplace also relates directly to residential location with the Borup-clusters (2b, 3b, 4) showing significantly higher median distances than the Østerbro-clusters (1, 2a, 3a).

If people had moved within the last five years, they were asked about their **former residential location**. For clusters 1, 2, and 4 the share of earlier locations (urban vs. non-urban) is largely corresponding to the current composition of these clusters by Østerbro and Borup residents. However, cluster 3, which consists of residents almost equally from Østerbro and Borup (see Table 3), has a significantly high share of inomers from non-urban settings.
4.3 Weekend trips and holidays

Comparing the differences between the modality styles in terms of **number of weekend and holiday trips**, the results revealed a very distinct pattern (see Table 5): **Committed cyclists** account in all trip categories, for which significant group differences could be found, for the significantly highest number of trips; except, only cluster 3a scores higher for holiday trips elsewhere in Europe.

On the other hand, cluster 2b (**public transport users – Borup**) is in all trip categories among the groups with the significantly fewest trips; and cluster 3b (**non-public transport users – Borup**) scores significantly low for holiday trips. This might be associated with the clusters’ socio-economic characteristics: 2b and 3b have the biggest household size and the lowest income per person (see Table 4). Hence, there is a tendency for more trips among the residents of Østerbro compared to the residents of Borup.

An interesting position is taken by cluster 4: In terms of weekend trips outside Denmark it shows almost as high frequencies (mean rank=177.073) as cluster 1 (180.807), whereas in terms of holidays it is located between the Østerbro and Borup scores, i.e. the ‘die-hard’ drivers undertook weekend trips outside Denmark almost as frequently as the cyclists but comparatively less holiday trips.

<table>
<thead>
<tr>
<th>Total N in each cluster</th>
<th>1 Committed cyclists</th>
<th>2 Public transport users (work)</th>
<th>3 Non-public transport users</th>
<th>4 ‘Die-hard’ car drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a Østerbro</td>
<td>2b Borup</td>
<td>2a Østerbro</td>
<td>2b Borup</td>
<td>2a Østerbro</td>
</tr>
<tr>
<td>Median</td>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.0</td>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>N</td>
<td>96</td>
<td>53</td>
<td>57</td>
<td>28</td>
</tr>
<tr>
<td>Mean rank</td>
<td>180.807</td>
<td>146.600</td>
<td>152.383</td>
<td>177.073</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of weekend trips outside Dk*</th>
<th>Median</th>
<th>N</th>
<th>Mean rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96</td>
<td>180.807</td>
<td></td>
</tr>
<tr>
<td>1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>110</td>
<td>146.600</td>
<td></td>
</tr>
<tr>
<td>1.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>64</td>
<td>152.383</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of holidays elsewhere in Europe*</th>
<th>Median</th>
<th>N</th>
<th>Mean rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89</td>
<td>171.410</td>
<td></td>
</tr>
<tr>
<td>1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>101</td>
<td>134.183</td>
<td></td>
</tr>
<tr>
<td>1.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>57</td>
<td>147.123</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Group differences related to number of weekend and holiday trips

*) significant group differences (p<0.05)

<sup>ab</sup>) different superscript letters denote significant group differences

Comparing **transport modes for weekend trips in Denmark** (see Table 6) disclosed significant differences between clusters 1 and 2a versus clusters 3 and 4, showing reciprocity between public transport and car use. Clusters 3 and 4 used almost exclusively (>90%) the car for their last weekend trip, which can be associated with car ownership (see Table 4) and corresponds to their modality style. However, also 60% of the committed cyclists (1), who never use the car to get to work and almost never in their daily free time (5.2%), used a car for their last weekend trip. Contrarily, among the public transport users more than 85% of the Borup residents (2b) but less than 45% of the Østerbro residents
(2a) used a car for their last weekend trip in Denmark; the latter appear to stick to public transport (46.8%) also for weekend trips.

When looking at **weekend trips outside Denmark**, cluster 2b shows, similar to trips in Denmark, even the highest share of car use (contrary the lowest share of plane use, together with cluster 3b). This might again be associated with the comparatively big household size and low income of these two clusters, as plane trips are more expensive and also cumbersome with children (similar to using public transport). However, due to a low number of responses with weekend trips outside Denmark, the differences in plane trips could not be qualified as statistically significant.

Looking at the **transport modes for holidays**, we found a similar reciprocal share of trips by public transport or car, respectively, between clusters 1 and 2a versus 4 (and 3b) as for weekend trips in Denmark.

**Plane use for holidays** is largely consistent with plane use for weekend trips; clusters 1 and 3a (both Østerbro) used the plane significantly most often.

<table>
<thead>
<tr>
<th>1 Committed cyclists</th>
<th>2 Public transport users (work)</th>
<th>3 Non-public transport users</th>
<th>4 'Die-hard' car drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total N in each cluster</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>53</td>
<td>57</td>
</tr>
<tr>
<td><strong>N %</strong></td>
<td><strong>N %</strong></td>
<td><strong>N %</strong></td>
<td><strong>N %</strong></td>
</tr>
<tr>
<td><strong>Last weekend trip in Dk by...</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car*</td>
<td>48(^{ab}) 60.0%</td>
<td>21(^b) 44.7%</td>
<td>36(^c) 85.7%</td>
</tr>
<tr>
<td>Public transport*</td>
<td>27(^b) 33.8%</td>
<td>22(^b) 46.8%</td>
<td>6(^c) 14.3%</td>
</tr>
<tr>
<td><strong>Last weekend trip outside Dk by...</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car*</td>
<td>14(^a) 22.6%</td>
<td>6(^a) 18.8%</td>
<td>14(^b) 63.6%</td>
</tr>
<tr>
<td>Public transport</td>
<td>9 14.5%</td>
<td>4 12.5%</td>
<td>0 0.0%</td>
</tr>
<tr>
<td>Plane</td>
<td>36 58.1%</td>
<td>20 62.5%</td>
<td>7 31.8%</td>
</tr>
</tbody>
</table>

*No. car use to holidays*:
- Median | 0.5\(^a\) |
- N | 84 |
- Mean rank | 113,369 |
- No. bus/ train use to holidays*:
- Median | 0.0\(^a\) |
- N | 84 |
- Mean rank | 151,798 |
- No. plane use to holidays*:
- Median | 1.0\(^a\) |
- N | 84 |
- Mean rank | 150,726 |
- Total No. of private plane trips*:
- Median | 1.0\(^a\) |
- N | 93 |
- Mean rank | 179,774 |

*) significant group differences (p<0.05)

ab) different superscript letters denote significant group differences

**) contains cells with expected counts less than 5

Table 6: Group differences related to mode choice for weekend trips and holidays

**4.4 Attitudes**

Using people’s travel-related attitudes (see Table 7) for contrasting their self-reported travel behaviour revealed a twofold result: We found that in terms of owning a car and eco-friendliness of daily mode choice, the stated attitudes largely conform to reported behaviour and corresponding modality styles:
The modality styles with the highest car ownership (clusters 3b and 4; see Table 4) expressed the highest agreement with the statement "Owning a car gives me freedom to go where- and whenever I want.", whereas the cluster with the lowest car ownership (2a) stated the least agreement with this statement.

In terms of eco-friendly daily transport modes⁷, the stated attitudes are coherent with the respective modality styles: Committed cyclists score highest for a ‘green’ attitude, whereas non-public transport users and ‘die-hard’ car drivers score the lowest.

<table>
<thead>
<tr>
<th></th>
<th>1 Committed cyclists</th>
<th>2 Public transport users (work)</th>
<th>3 Non-public transport users</th>
<th>4 ‘Die-hard’ car drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total N in each cluster</strong></td>
<td>96</td>
<td>53</td>
<td>57</td>
<td>28</td>
</tr>
<tr>
<td><em>Car – freedom</em>*</td>
<td>1.0</td>
<td>1.0†</td>
<td>1.0</td>
<td>1.0⁹</td>
</tr>
<tr>
<td>N</td>
<td>44</td>
<td>17</td>
<td>49</td>
<td>24</td>
</tr>
<tr>
<td>Mean rank</td>
<td>117.477</td>
<td>132.647</td>
<td>108.939</td>
<td>108.917</td>
</tr>
<tr>
<td><strong>Environmentally friendly daily transport</strong></td>
<td>1.0</td>
<td>1.0⁹</td>
<td>3.0⁶</td>
<td>3.0⁷</td>
</tr>
<tr>
<td>N</td>
<td>93</td>
<td>108</td>
<td>62</td>
<td>52</td>
</tr>
<tr>
<td>Mean rank</td>
<td>112.602</td>
<td>159.139</td>
<td>175.839</td>
<td>215.558</td>
</tr>
<tr>
<td><strong>Environmentally friendly weekend/holiday transport</strong></td>
<td>3.0⁶</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0⁹</td>
</tr>
<tr>
<td>N</td>
<td>93</td>
<td>108</td>
<td>62</td>
<td>52</td>
</tr>
<tr>
<td>Mean rank</td>
<td>139.151</td>
<td>161.259</td>
<td>158.081</td>
<td>184.846</td>
</tr>
<tr>
<td><strong>Trips are important</strong></td>
<td>1.0</td>
<td>1.0²</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>N</td>
<td>93</td>
<td>51</td>
<td>57</td>
<td>27</td>
</tr>
<tr>
<td>Mean rank</td>
<td>141.952</td>
<td>150.206</td>
<td>181.868</td>
<td>151.074</td>
</tr>
</tbody>
</table>

*) significant group differences (p<0.05)
*ab,*) different superscript letters denote significant group differences

Table 7: Group differences related to travel-related attitudes

The attitudes regarding weekend and holiday travel, however, conform only to some extent to self-reported behaviour:

With regards to the importance of weekend and/or holiday trips⁸, the reported trip numbers are in accordance with the stated attitudes: Committed cyclists (1) stated significantly highest importance and accordingly went most frequently on trips, whereas clusters 2b and 3b (both Borup) stated the lowest importance and accordingly undertook the fewest trips. This suggests that a combination of the factors income, household size and attitude, which are themselves interrelated, explain the limited travel activity of clusters 2b and 3b.

However, when it comes to the eco-friendliness of weekend or holiday transport modes⁹ we found discrepancies between attitudes and self-reported behaviour: ‘Die-hard’ car drivers give least importance to eco-friendly weekend/holiday transport and used the car correspondingly most often; however, they instead rarely used a plane. In contrast, committed cyclists, who stated the highest importance for eco-friendly weekend/holiday transport, used (together with cluster 2a) public transport relatively often, but on the other hand, they used the plane comparatively most often; and for weekend trips in Denmark, they also used the car. Obviously, the committed cyclists’ attitudes are contradictory to their travel behaviour, particularly in terms of plane use.

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⁶ Note: Only households who stated that they owned at least one car were asked about this attitude.
⁷ "It is important for me that my transport mode in daily life is environmentally friendly."
⁸ "Weekend trips and/or holidays are important for me."
⁹ "It is important for me that my transport mode to weekend trips and holidays is environmentally friendly."
5 Discussion

*Modality styles and urban structure*

Clustering the sample of residents from Østerbro and Borup based on daily mode choice revealed four distinct modality styles: *Committed cyclists, public transport users, non-public transport users and die-hard’ car drivers*. Two of them, *committed cyclists* and *die-hard’ car drivers*, are primarily represented in Østerbro and Borup, respectively, indicating a predominant modality style in each case area. Østerbro is representing Copenhagen’s cycling culture (e.g. Carstensen and Ebert, 2012). A recent study (Prato et al., 2016) that investigated transport mode choices from a lifestyle perspective, also in the Copenhagen Region, largely confirms our results: The study arrived at four similar groups: *car oriented, bicycle oriented, public transport oriented, and public transport averse* with corresponding differences in residential location (centre vs. surroundings of Copenhagen). Also, Olafsson et al. (2016) found that cycle-based travel predominantly takes place in larger urban areas, whereas car-based transport is dominant in small urban/suburban areas. In terms of multimodality our findings appear to deviate from those of Olafsson et al. (2016), who attested Danes multimodal travel behaviour. The deviations are likely explained by the data collection methods, as we asked how people “mostly” get to work/education/free-time activities, whereas Olafsson et al. (2016) inquired the number of days respondents used different transport modes over the course of one week. Furthermore, the here identified groups *public transport users* and *non-public transport users* are multimodal.

The study’s identified modality styles confirm the relevance of urban structure for travel mode choice (e.g. Naess, 2006) as represented by the two distinct case areas. However, *public transport users* and *non-public transport users* are equally represented in both case areas; this indicates the relevance of further factors for the establishment of modality styles, such as car ownership, household size, income, or ‘imported’ travel behaviour. The significant amount of people among the *non-public transport users* who moved in from non-urban settings indicates that some people might ‘import’ their past travel disposition (see Klingner and Lanzendorf, 2016) and do not necessarily adopt the new setting’s predominant modality style. This has been conceptualised as *residential dissonance or mismatch* (de Vos et al., 2012; Schwanen and Mokhtarian, 2005).

*Modality styles and weekend/holiday travel*

When relating daily modality styles to *weekend and holiday travel*, it appears that differences are explained at two levels, by accounting for *modality styles* and *residential location*, as shown when splitting the *public transport users* and *non-public transport users* into their Østerbro/Borup sub-sample.

Overall, *committed cyclists* most frequently undertook weekend and holiday trips, and in general, there is a tendency for more trips among respondents from Østerbro.

In terms of *transport modes*, the ‘die-hard’ drivers stick to the car also for weekend/holiday travel. *Public transport users – Østerbro and committed cyclists* have the fewest cars and used them least often for weekend/holiday trips; however, the car still accounts for a considerable share (60%) of weekend trips in Denmark among *committed cyclists*. *Public transport users* manifest the relevance of residential location by behaving like their ‘residential peers’: Those from Østerbro tend to use the plane and to a certain extent public transport for weekend/holiday trips; those from Borup predominantly use the car. Except for weekend trips in Denmark among *public transport users – Østerbro*, the use of public transport plays a minor role for weekend and holiday trips, as also confirmed by a previous study on Danes’ travel behaviour (Christensen, 2014).
Overall, it appears that ‘die-hard’ drivers avoid using modes other than the car; they hardly use public transport, and apparently use a plane only when it is inevitable (e.g., for weekend trips outside Denmark). Cyclists, who travel ‘greenest’ in daily life, use the plane most often. Overall, plane use is lower in Borup than in Østerbro, i.e. significant group differences emerged only when accounting for residential location (see Table 6). These findings are in line with those of Prillwitz and Barr (2011), who arrived to similar characteristics, particularly for the ‘green’ daily travellers.

According to our results, car drivers and cyclists – and to a certain extent public transport users – tend to use one main transport mode in daily work and leisure life. If this transport mode is suitable (e.g., car, public transport) it is to a certain extent transferred for weekend/holiday travel. However, if the main transport mode (e.g., cycling) is not suitable, which is usually the case for non-motorised modes, its users switch even more than the first group to unsustainable modes such as planes. Our study does not, however, assess the effect of accessibility to an airport and cheap flights on the one hand, compared to the high expenses of owning a car in Denmark on the other hand, which presumably affects mode choices.

In summary, we observe interdependency between modality style, residential location, car ownership/use, and plane use for weekend/holiday travel. People in urban areas have less access to cars, but instead use planes more often. People in peri-urban areas have in contrast more access to cars (and less to an airport) and consistent with their daily mode choice, predominantly use the car, which is line with the findings of Lanzendorf (2002).

The contrast between daily and weekend/holiday travel behaviour has been further illustrated by looking at the respondents’ attitudes: In terms of owning a car, eco-friendliness of daily transport, and importance of weekend or holiday trips, the stated attitudes are largely in accordance with self-reported behaviour for all modality styles. However, when it comes to mode choice for weekend/holiday trips, particularly the committed cyclists ‘behave’ rather contrary to their eco-friendly attitude, especially regarding plane use. On the other hand, the ‘die-hard’ car drivers’ eco-commitment is more in line with their self-reported behaviour.

This discrepancy between behaviour and attitudes is confirmed by previous studies that found that people “find it difficult to align their behaviour with their environmental attitudes during their leisure time” (Holden and Linnerud, 2011, p. 3099) and that assessed limited influence of environmental attitudes on weekend/holiday behaviour (Böhler et al., 2006; Holden, 2007; Prillwitz and Barr, 2011).

**Weekend/holiday travel and urban structure**

Relating the four modality styles to weekend/holiday travel suggests at first glance a ‘reverse’ effect of urban structure: The eco-friendly daily behaviour of the urban cyclists and public transport users is replaced by environmentally harmful modes and comparatively high trip frequencies in weekend/holiday travel.

However, the stated attitudes in terms of importance of trips (stronger agreement in Østerbro) as well as the socio-economic and socio-demographic differences (lower income, bigger household sizes in Borup), indicate that the observed differences in weekend/holiday travel (also) originate in other factors such as lifestyle, family status or wish to travel. Also Böhler et al. (2006) found that trip activity is associated with socio-economic and socio-demographic factors such as household type. Additionally, we can assume that certain lifestyles are predominant in certain residential locations (residential self-

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10. Transport mode choices for weekend trips outside Denmark might be more restricted due to distance and limited time (only weekend), many destinations are only reachable by plane.
selection], which is demonstrated in the trend of young families moving outside central Copenhagen (Aner, 2016; Hansen, 2015). This makes residential location a proxy for those other factors.

We conclude that weekend/holiday travel is not primarily explained by urban structure but rather by underlying residential choices and related lifestyles; however, we cannot exclude a direct effect of urban structure on weekend/holiday travel.

Our study encountered some limitations with regards to a limited number of respondents and statistical methods that do not account for multivariate relationships across the included factors. Nevertheless, the range of results allow for some relevant conclusions.

6 Conclusions

We can assert that the urban structure of a residential location (e.g., urban vs. peri-urban) influences the constitution of predominant daily modality styles; however, the mixed representation of public transport users and non-public transport users indicates the importance of further factors.

When relating the identified modality styles to weekend and holiday travel, we deduce a link between modality style, residential location, and weekend/holiday travel (frequency and mode choice). This link is understood when accounting for socio-economic and socio-demographic factors as well as travel-related attitudes. Hence, our findings support the notion of modality styles as expressions of mobility styles (Vij et al., 2013), as they illustrate the link between travel behaviour and factors, such as socio-economic factors or attitudes, that underlie residential location.

Consequently, according to our findings, residential location has a somewhat paradoxical role: For daily travel, the urban structure of a residential location exerts important influence on travel behaviour; however, in terms of weekend/holiday travel, residential location presumably rather serves as a proxy for certain lifestyles or people with certain socio-economic and socio-demographic characteristics.

Our study does not allow for comparing the four modality styles in terms of the effective environmental impact of their travel behaviour. However, obviously their impacts differ in daily travel, but in weekend/holiday travel the four modality styles close ranks.

The discrepancy between daily and weekend/holiday travel behaviour, which is also found in previous studies (e.g. Barr and Prillwitz, 2012; Prillwitz and Barr, 2011), requires increased attention in spatial development and transport policies. It appears that policies tailored for sustainable everyday travel have little or even adverse effects on certain leisure travel (Holden and Linnerud, 2011). Thus, policies that address travel behaviour comprehensively as well as such that tackle weekend and holiday travel in particular are needed.

What makes people travel more sustainably? In daily life it is probably not only an eco-friendly attitude of the residents of Østerbro, but the fact that cycling is the most efficient way to move within Copenhagen. The weekend/holiday travel behaviour of the same group confirms that attitudes hardly affect travel mode (plane, car) choices.

Our research suggests that public transport is currently underutilised for weekend/holiday travel; thus, additional research is required on what prevents people from using it and what kinds of transport policies are needed for making public transport, e.g., in terms of speed, convenience, price, a competitive choice compared to car or plane use, at least for short- and medium-distance trips. Suggestions include multimodal travel passes (e.g. Sauter-Servaes and Nash, 2009) that allow combining different types of public transport, car sharing systems, and public bicycle schemes. Furthermore, in Europe, reactivating attractive night train connections instead of continuing their shutdown could offer com-
petitive alternatives to plane use, in terms of time efficiency and price. Yet, improvements to the reputation and perception of public transport are also crucial; the idea of a free InterRail pass sponsored by the European Union for all 18-years-olds (Calder, 2016) appears ground-breaking.

Finally, policies that set economic or regulative constraints appear inevitable. Considering, for instance, that limited expenses for daily travel (e.g., when cycling) increase the disposable budget for weekend and holiday travelling, after all. Likewise, car use is also a question of affordability. Road-pricing (Klinger and Lanzendorf, 2016), a personal carbon budget (Prillwitz and Barr, 2011), or CO₂-emission charges (Holden and Linnerud, 2011) are only a few suggestions worth investigating.

We conclude that for understanding how to change travel behaviour there is a need for further research incorporating approaches (e.g., the theory of planned behaviour) that focus on intentions and attitudes that determine individual behaviour to, for instance, better understand constraints regarding public transport use.

7 Acknowledgements

The authors would like to thank Frank Søndergaard Jensen for his valuable comments on the questionnaire design.

8 Conflicts of interest

The authors declare that there is no conflict of interests.
9 References


Calder, S., 2016. Every 18-year-old could soon have free air, sea and bus travel - if they’re an EU citizen. The Independent.


Christensen, H., Skougaard, B.Z., 2015. The Danish National Travel Survey - declaration of variables (No. TU 2006-14, version 2). Technical University of Denmark, Department of Transport, Lyngby.


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### Gender
- **Female**: 77.1% (59), 52.9% (45), 53.2% (49), 50.9% (49)
- **Male**: 22.9% (22), 47.3% (45), 46.9% (49), 49.1% (49)

### Location before moving
- **Urban**: 22 (18), 18 (96), 4 (3), 19.0% (3), 23.9% (22)
- **Non-urban**: 12.0% (9), 41.9% (45), 41.0% (50), 76.9% (50)

### Age
- **Median**: 49.0% (10), 49.00% (10), 51.0% (10), 49.0% (10)
- **Mean rank**: 96 (110), 1.10 (64), 64 (55)

### Education level
- **Median**: 3.0 (5), 3.0 (5), 3.0 (5), 3.0 (5)
- **Mean rank**: 183.91 (110), 140.68 (64), 142.74 (55), 160.09 (55)

### Household size
- **Median**: 2.0 (5), 2.1 (5), 2.0 (5), 2.0 (5)
- **Mean rank**: 138.26 (64), 161.46 (55), 146.55 (55), 154.76 (64)

### Income per person (in)
- **Median**: 12.66 (5), 12.478 (4), 12.554 (4), 12.595 (4)
- **Mean rank**: 140.57 (5), 121.76 (4), 138.75 (5), 133.739 (4)

### Work distance (in of km)
- **Median**: 1.792 (5), 3.219 (4), 2.966 (5), 3.555 (4)
- **Mean rank**: 80.130 (5), 202.278 (4), 160.516 (5), 221.645 (4)

### Number of cars per household
- **Median**: 0.0 (5), 1.0 (5), 1.0 (5), 44.0% (5)
- **Mean rank**: 117.533 (64), 140.595 (55), 207.173 (55), 235.773 (55)

### Number of weekend trips in DK/Skåne
- **Median**: 1.5 (4), 2.0 (4), 4.0% (4), 3.0 (4)
- **Mean rank**: 162.583 (4), 150.834 (5), 174.143 (4), 175.145 (4)

### Number of holidays on Zealand
- **Median**: 0.0 (4), 0.1 (4), 0.0 (4), 0.0 (4)
- **Mean rank**: 153.152 (5), 146.089 (4), 141.395 (4), 156.160 (4)

### Number of holidays elsewhere in Denmark
- **Median**: 0.0 (4), 0.0 (4), 0.0 (4), 0.0 (4)
- **Mean rank**: 153.600 (5), 143.337 (4), 145.000 (5), 156.801 (4)

### Number of holidays elsewhere in Scandinavia
- **Median**: 0.0 (4), 0.0 (4), 0.0 (4), 0.0 (4)
- **Mean rank**: 09.4 (4), 101 (4), 37 (4), 50 (4)

### Number of holidays elsewhere in Europe
- **Median**: 10 (4), 10 (4), 10 (4), 10 (4)
- **Mean rank**: 171.410 (5), 134.183 (4), 147.123 (5), 141.180 (5)

### Number of holidays outside Europe
- **Median**: 0.0 (4), 0.0 (4), 0.0 (4), 0.0 (4)
- **Mean rank**: 153.978 (4), 151.663 (5), 136.368 (5), 149.160 (5)

### Total number of holidays
- **Median**: 3.5 (4), 3.0 (4), 3.0 (4), 3.0 (4)
- **Mean rank**: 184.022 (5), 128.777 (5), 132.105 (4), 146.770 (4)

### Last weekend trip in DK by ...
- **Car**: 60.0% (4), 64.0% (4), 92.3% (4), 93.6% (4)
- **Public transp.**: 27 (4), 28 (4), 3 (4), 3 (4)
- **Other**: 33.8% (4), 31.5% (4), 5.9% (4), 5.9% (4)

### Last weekend trip outside DK by ...
- **Car**: 48 (5), 37 (5), 44 (5), 44 (5)
- **Public transp.**: 20 (5), 24 (5), 34 (5), 34 (5)
- **Other**: 6.39% (5), 4.6% (5), 1.9% (5), 1.9% (5)

### Number of car use to holidays
- **Median**: 0.0 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 113.369 (4), 126.077 (5), 141.700 (5), 164.875 (5)

### Number of ferry use to holidays
- **Median**: 0.0 (4), 0.0 (4), 0.0 (4), 0.0 (4)
- **Mean rank**: 136.895 (4), 134.960 (5), 130.120 (5), 117.885 (5)

### Number of bus/train use to holidays
- **Median**: 0.0 (4), 0.0 (4), 0.0 (4), 0.0 (4)
- **Mean rank**: 151.798 (4), 137.583 (5), 113.380 (5), 104.000 (4)

### Number of plane use to holidays
- **Median**: 1.0 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 150.726 (5), 127.964 (5), 125.460 (5), 108.409 (5)

### Total number of private plane trips
- **Median**: 0.0 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 179.724 (5), 205.204 (5), 149.944 (5), 144.856 (5)

### Attitudes / trips are important [1 - agree ... 3 - disagree]
- **Median**: 1.5 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 141.952 (5), 169.017 (5), 173.313 (5), 149.363 (5)

### Attitudes / environmentally friendly daily transport [1 - agree ... 3 - disagree]
- **Median**: 1.5 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 112.602 (5), 159.139 (5), 175.839 (5), 215.558 (5)

### Attitudes / environmentally friendly weekend/holiday transport [1 - agree ... 3 - disagree]
- **Median**: 1.5 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 139.151 (5), 165.259 (5), 158.081 (5), 184.844 (5)

### Attitudes / owning_car_frequency [1 - agree ... 3 - disagree]
- **Median**: 1.5 (4), 1.0 (4), 1.0 (4), 1.0 (4)
- **Mean rank**: 117.477 (5), 115.045 (5), 105.632 (5), 102.058 (5)

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Paper IV

Compensating for compactness? Leisure travel of city dwellers vs. small town dwellers in Greater Copenhagen

By Juliane Große, Christian Fertner, Trine Agervig Carstensen

Submitted to Travel Behaviour and Society, 2016 (in peer-review)
Compensating for compactness? Leisure travel of city dwellers vs. small town dwellers in Greater Copenhagen

Juliane Große, Christian Fertner, Trine Agervig Carstensen
Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark

Abstract
Compact urban development is considered a paradigm for sustainable development. However, compact cities are also characterised by high densities that may imply counter effects such as limited access to green spaces or nature areas for leisure activities, or reduced air quality. People living in compact urban areas might respond to these counter effects by ‘compensatory activities’ such as higher amounts of leisure travel. In this study, we compare the leisure travel behaviour of people living in a dense urban district in central Copenhagen, Denmark, with that of people living in a small town in the commuter belt of Copenhagen. The study uses a questionnaire survey to examine the relationship between people’s living environment and their leisure travel behaviour. The results show that city dwellers go more frequently on weekend, holiday and plane trips and choose more distant destinations compared to small town dwellers. Access to a summer cottage and related weekend trips appear as some sort of compensatory behaviour among city dwellers; however, lifestyle and residential choice turn out to be stronger determinants.

Keywords: air travel, free time, rebound effect, sustainability, travel behaviour, urban planning, urban structure
1 Introduction

Sustainable urban development is not a concern addressed by a comprehensive responsibility. Urban energy efficiency requires deliberate actions on savings as well as production of energy by, e.g., the city council, residents of the city, its enterprises and public utilities. Urban planning has an important role in developing an urban structure that facilitates energy efficiency in the daily urban activity flows by distributing urban functions (workplaces, services, residential and recreational areas, etc.) and providing efficient connections between them.

The impacts of urban structure on energy consumption in cities have been comprehensively researched. Compact urban structures facilitate efficient energy use by for instance reducing the daily commute (Fertner and Große, 2016; Große et al., 2016). However, a further branch of research looks into the counter effects or contradictions (Breheny, 1992) of compact urban structures that might result in so-called ‘rebound effects’ (EEA, 2013) or ‘compensatory activities’ (Naess, 2016). Rebound effects can be direct, such as compensatory leisure travel, or indirect, such as increased consumption of other goods and services (Heinonen et al., 2013, 2011; Heinonen and Junnila, 2011; Poom and Ahas, 2016). Compensatory activities are assumed to partly offset the efficiency gains of compact urban structure by consuming more energy in other domains (Holden, 2007; Holden and Norland, 2005; Naess, 2016; Vilhelmsen, 1990).

This is especially critical in the more wealthy Western European countries, where long-distance travel (≥ 100 km) is estimated to account for probably almost 50% of the greenhouse gas (GHG) emissions from travel (van Goeverden et al., 2016). In Norway, long-distance trips account for even 68% of the total climate impact or 55% of the CO₂-emissions (Aamaas and Peters, 2017); and in Denmark 31% of the CO₂-emissions from passenger travel are caused by international travel (Christensen, 2016). Nevertheless, long-distance travel is not sufficiently researched yet (van Goeverden et al., 2016) and studies that have addressed leisure travel have come up with partly contradictory explanations for observed higher amounts of leisure travel among city dwellers (e.g. Dijs et al., 2005; Holden and Norland, 2005; Naess, 2006). Hence, understanding and explaining leisure travel, especially medium- and long-distance, requires increased attention.

The aim of this study is to identify and explain a potential relationship between the urban structure of people’s living environment and their leisure travel behaviour. We compare the leisure travel of people residing in two different types of living environment: a dense urban district in Copenhagen (‘urban case’) and a small town in the commuter belt of Copenhagen (‘peri-urban case’).

We aim to (1) identify differences between the two populations’ leisure travel behaviour in weekend (max. 3 nights) and holiday trips (more than 3 nights) as well as the use of air travel; and (2) explain whether potential differences can be qualified as ‘compensatory activities’, i.e. triggered by a certain urban structure of the living environment, or if other significant determinants can be found.

Existing studies mostly refer either to a single case or use multiple cases with similar urban structure characteristics (e.g., medium-size cities) and define differences in the living environment by, e.g., distance to the city centre. Our study examines two cases with two distinct types of living environment (‘urban case’ vs. ‘peri-urban case’).

We further contribute with an approach that aims to account for lifestyle-related factors by including people’s motives (for a certain behaviour) and satisfaction with specific features of their living environment. Finally, we discuss the role and possibilities of urban planning in dealing with leisure travel.
2 Framing compensatory leisure travel – A brief review

2.1 Sustainable urban structure as a trade-off

Research on energy consumption in urban areas and the influence of urban structure provides evidence that compact urban structures, concentrated development and mixed urban functions favour an efficient use of energy in cities. Compact urban structures affect travel behaviour as they limit the need to travel and facilitate environmentally friendly transport modes (Fertner and Große, 2016; Große et al., 2016).

However, urban development underlies diverse drivers and priorities for different development aims. Prioritising one aim (e.g., energy efficiency or quality of life) might imply trading off another aim. Westerink et al. (2013, p. 477) explain that 'a gain in one sustainability dimension may be accompanied by a loss in another dimension'. Related to shaping specific living environments, urban planning involves trading off different features and qualities – such as compactness and density of the built-up area, access to public transport or green spaces and leisure activities, air quality (Schindler and Caruso, 2014) or environmentally sensitive and intrusive urban functions such as sources of noise or emissions (de Roo, 2000).

Balancing the benefits and counter effects of compact urban structure represents a challenge to sustainable urban development and related policies (OECD, 2012).

2.2 Compensatory leisure travel

Existing academic literature and empirical work indicate that the energy efficiency benefits of sustainable urban structure can partly be offset by compensatory activities, such as leisure travel; this is conceptualised as the so-called 'compensation hypothesis'. However, the explanations for the observed higher amounts of leisure travel among city dwellers point – besides compensation – in diverse directions.

Næss (2006) conducted a study for the Copenhagen Metropolitan Area for testing the compensation hypothesis. The study considers weekend travel, leisure trips outside the island of Zealand, access to summer cottages as well as holiday trips and flights. The results indicate some sort of compensatory travel among inner-city Copenhageners in terms of more trips outside the island of Zealand, longer travel distances at weekends and trips to nature areas, which, however, do not outweigh the energy related benefits of compact and dense urban living. Higher frequencies of flights among urban dwellers are, in contrast, rather attributed to a surplus in money due to savings, for instance in car ownership, and a more 'cosmopolitan' lifestyle, than 'escape' from the dense city (Næss, 2006). A later study, in which also Stavanger and Oslo in Norway are included in addition to Copenhagen arrives at similar conclusions (Næss, 2016).

A study on the Greater Oslo Region (Holden and Norland, 2005) provides evidence that access to a private garden is associated with less leisure-time travel by car and plane, even in areas of high-density housing. But, the study also acknowledges that access to a garden might simply express the wish to spend time in a garden. The same study identifies a relation between high-density housing and energy use for air travel, which is considered as a 'possible long-term indirect effect of high-density living' (Holden and Norland, 2005, p. 2162). A Finnish study (Ottelin et al., 2014) confirms that in dense urban areas air travel contributes significantly to GHG emissions from private travel and thereby 'breaks the pattern of decreasing GHG emissions with increasing density of urban forms' (Ottelin et al., 2014, p. 6).

In addition to the adjacencies of the living environment, further studies also include the ownership or use of summer cottages or second homes, which turns out to be an indicator for potentially higher
leisure travel: A study on second home ownership in Germany and the Netherlands (Dijst et al., 2005) shows mixed results in terms of the compensation hypothesis, however, in the Netherlands owners of second homes and in Germany allotment owners seem to frequently compensate for their urbanised living environment. The authors describe them as ‘escapers’ (compared to ‘holidayers’ or ‘enjoyers’), who are escaping from busy daily life (Dijst et al., 2005, p. 150). A study on second home use in Finland (Strandell and Hall, 2015) provides further support for the compensation hypothesis as it finds that density of the residential environment and lack of a private garden are related to more intensive use of second homes. Naess’ (2006) findings from the Copenhagen study show, in contrast, no explicit relationship between dense urban living and summer cottage access.

Summarising, some of the existing studies on compensatory leisure travel indicate the existence of compensatory activities, though, other studies explain more extensive leisure travel rather by socio-economic or lifestyle-related factors. A comprehensive study looking at various motivations for travel from a psychological theory perspective (Mokhtarian et al., 2015) considers the ‘need to escape’ as one driver, besides others, for tourism. Hence, explaining leisure travel behaviour requires accounting for a combination of factors, as Reichert et al. (2016) also conclude; they highlight, among others, urban lifestyle, compensatory/escape trips (rebound effect), access to transport infrastructure and residential self-selection as reasons for the differences in long-distance travel between urban and rural populations.

2.3 Linking urban structure and leisure travel

For the present study, we built upon the findings on understanding and explaining leisure travel from the above presented studies, which take different foci for looking at leisure travel. However, they provide a very relevant scope of explanatory factors for leisure travel. We combined them (see Figure 1) to shed light on the relationship between the urban structure of people’s living environment (1) and their (potentially compensatory) leisure travel behaviour (2).

![Figure 1: Relationship between people’s living environment and their travel behaviour.](image)

The suggested explanatory factors involve concepts such as traveltime budget (3) and residential self-selection (4) as well as socio-economic characteristics, such as income, and people’s preferences and lifestyles (5) that are mutually interdependent and frame travel behaviour and patterns.

The ‘traveltime budget hypothesis’ (3) goes back to Zahavi (1974) and was further developed and applied by, e.g., Vilhelmsen (2007, 1990) supposing that people have a constant traveltime budget that leads to rebound. Comparable effects are assumed regarding money budgets for travel. Holden and Linnerud (2015) suggest that due to fixed time and money budgets for travel, people may compensate savings in everyday travel by increasing leisure travel.
Another determining condition for travel behaviour is 'residential self-selection' (4). It supposes that people base their residential choice on their travel needs, abilities and preferences (van Wee, 2009). People 'choose a residential location that conforms to their travel-related attitudes' (Bohle et al., 2009, p. 326), but also to their 'travel-liking attitudes' (de Vos and Witlox, 2016, p. 37). According to this understanding, not urban form but people's attitudes would primarily determine travel behaviour. On the other hand, as van Wee (2009, p. 282) points out, 'attitudes towards travel might be influenced by location-based experiences', thus, influenced by urban form. Also Næss (2009, p. 298) considers the built environment as 'a variable prior to residential self-selection' emphasising the importance of urban structure for travel behaviour.

The close interrelation between lifestyle-related preferences and residential choices (5) is illustrated by three Danish studies, which identify disposition (habitus, personal tradition) (Ærø, 2006) as well as preferred living environment for families with children and capability (affordability) to achieve that in a big city like Copenhagen (Aner, 2016; Fertner, 2013) as relevant reasons for residential choices. However, lifestyle and socio-economic factors (5) also have a direct influence on travel behaviour: A German study on holiday travel behaviour identifies differences in lifestyle and socio-economic characteristics between non-, local, mid-distance or long-haul travellers (Böhler et al., 2006). Van Acker et al. (2016) consider travel behaviour as an expression of a certain lifestyle and emphasise, thus, the importance of lifestyle for travel behaviour research.

The above framework illustrates that studying and understanding compensatory leisure travel as an outcome of a certain urban structure of the living environment requires incorporating additional explanatory concepts. In the following section, we describe, based on the framework introduced above, the methodical setup that we applied for our study on Greater Copenhagen.

3 Methods and data

The paper is based on questionnaire survey data from Østerbro (Copenhagen municipality) and Borup (Køge municipality, both Denmark).

3.1 Study cases

Østerbro is an inner district of Copenhagen with about 76,800 inhabitants in March 2016 (Københavns Kommune, 2016) and an area of 8.74 km². Borup is a small town with about 4,600 inhabitants in 2016 (Statistics Denmark, 2016) and an area of 2.6 km². Borup is located about 55 km southwest of Copenhagen centre and thereby in daily commuting distance to Copenhagen as well as to Roskilde, the second largest city on Zealand with a distance of about 20 km north of Borup (see Figure 2).
The cases are ‘paradigmatic’ for either ‘central urban living’ (Østerbro) or ‘peri-urban small town living’ (Borup) and represent the contradicting priorities of ‘urban desirability’ of compact spatial structures versus ‘suburban liveability’ (Neuman, 2005). Differences in the urban structure of the living environment, i.e. in terms of housing density and housing types (apartment vs. detached houses), compactness, accessibility of facilities and public transport, availability of green spaces, as well as distance to a regional centre, form the main comparative dimension between the two cases. Furthermore, we aimed to choose cases that show a comparable socio-economic profile in terms of, e.g., income and workforce participation, in order to limit the socio-economic differences and maximise instead the explanatory power of urban structure and lifestyle-related factors.

3.2 Sampling method

The questionnaire survey was carried out as an online survey in May and June 2016. Given an internet penetration rate of 94% in 2016 in Denmark (European Commission, Eurostat, 2016) and the targeted age group (18-65 years) this was judged as an appropriate distribution method.

In Østerbro an online panel provider was used to sample and distribute the questionnaire via e-mail. The response rate of completed surveys was 31.7%. In Borup each household, except housing for elderly people and nursing homes (‘plejejæm’), received a written invitation with a link to the online questionnaire; in total 1,874 households received an invitation. The response rate of completed surveys in Borup from the letter invitations was 9.3%. We additionally placed advertisements in the local newspaper (Lørdagsavisen, 2 June 2016), the local library and supermarkets in Borup to promote and access the survey.

The questionnaire was designed to be answered by one person per household, aged between 18 and 65 years, in order to focus on the working population. Respondents outside this age group were included for the data analysis if they were part of the working population. Due to these limitations, we discarded some responses from Borup and one from Østerbro for the data analysis. The final sample consists of 239 complete responses in Østerbro, 144 in Borup in response to the written invitation and another 13 in Borup from the additional advertisements. Furthermore, we included 23 partially complete responses in Østerbro, 18 in Borup from the written invitation and another two in Borup from the additional advertisements in the final sample. The final sample consists of 439 responses in total.
The Østerbro sample deviates from the district’s average in age (underrepresentation of younger and overrepresentation of older population) and gender (overrepresentation of women). The Borup sample deviates only slightly from the town’s average with an overrepresentation of participants in the age group of 45-64 years. This was considered in the interpretation of the results.

3.3 Survey design and variables

The questionnaire is based on the framework described above (Figure 1). For designing the questions we departed from existing parameter sets used in previous studies on travel behaviour (e.g. Dieleman et al., 2002; Næss, 2009, 2006; Næss and Jensen, 2004; Silva et al., 2015) and complemented with additional parameters regarding satisfaction with the living environment and lifestyle-related attitudes (e.g. Banerjee and Hine, 2014; Lim, 2016). Furthermore, we considered nationwide statistics such as The Danish National Travel Survey (Christiansen and Skougaard, 2015) and Statistics Denmark to provide comparability of results.

The questionnaire investigated, among other things, people’s weekend, holiday and plane trips within the last 12 months (see appendix), their living conditions and environment, including personal satisfaction with specific features of the living environment, whether people had moved within the last five years, general statements on attitudes related to ‘urban’ or ‘small town living’ and, finally, location of their workplace, demographic and socio-economic parameters.

Table 1 summarises the dependent and independent variables we used for the statistical analysis. According to the research question, we used three predictands – number of weekend trips, holiday trips and plane trips within the last 12 months. Plane trips are – besides weekend and holiday trips – a well suited additional measure to size travel activities and commonly used in studies on medium- and long-distance leisure travel, as the reviewed literature shows.
Table 1: Variables used in the statistical analysis.

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<td><em>Number of holiday trips (more than 3 nights) within last 12 months – total / ‘in Denmark’ / ‘elsewhere in Europe’ / ‘outside Europe’ (categorical frequencies per destination)</em></td>
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<td><em>Number of private plane trips within last 12 months (categorical frequencies)</em></td>
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<td><em>Highest completed level of education (categorical)</em></td>
</tr>
<tr>
<td></td>
<td><em>Logarithm of income per person per household (Danish kroner)</em></td>
</tr>
</tbody>
</table>

3.4 Statistical analysis

The statistical analysis was performed with a cumulative odds ordinal logistic regression with proportional odds (Laerd Statistics, 2015; Norušis, 2011; Schendera, 2014) using the PLUM (Polytomous Universal Model) procedure of IBM SPSS Statistics 22. Additionally we used the GENLIN (Generalized Linear Models) procedure to review and assess the model fit (e.g., with Akaike’s Information Criterion (AIC)).

The PLUM procedure allows only one dependent variable at a time, therefore we ran separate ordinal regression models for the different predictands (weekend / holiday / plane trips) – for each with the total number of trips and number of trips per destination. For the total number of weekend or holiday trips we aggregated the individual frequencies per destination (see appendix) and subsequently assigned the totals into categories according to the questionnaire. We compared different aggregation modes (e.g., based on the lower limit or mean of the respective frequency categories) and chose according to model fit and stability of results.

In each initial regression model, we included the complete set of predictors (see Table 1) and discarded stepwise single predictors based on model fit and validity. Therefore, the final sets of predictors vary between the models. For polytomous predictors that passed the overall test of statistical significance (omnibus test, \( p<0.05 \)) we tested for significance for each of the predictor’s values by changing

¹ Skåne (English: Scania) is the southernmost county of Sweden, which can be considered as part of the Greater Copenhagen Region based on distance.
the reference category in the same model (SPSS uses by default the last category as the reference category).

The high number of included predictors might raise concern about multicollinearity problems. We conducted pre-tests between possible collinear predictors before including them in the model. Due to applying ordinal regression some combinations of predictor values do not exist (cells with zero frequencies), which was considered in the evaluation of the goodness-of-fit tests (Laerd Statistics, 2015). We additionally conducted a Mantel-Haenszel test of trend (Laerd Statistics, 2016) to determine whether a linear association between the total number of weekend trips and the total number of holiday trips exists. We used the Crosstabs and the Bivariate Correlation procedure (Pearson’s) of IBM SPSS Statistics 22.

4 Results

We conducted a cumulative odds ordinal logistic regression with proportional odds. All final models meet the proportional odds assumption as confirmed by the test of parallel lines. According to the likelihood-ratio tests, all final models predict statistically significantly (p<0.05) the dependent variable over and above the intercept-only model.

4.1 Weekend trips

Comparing the number of weekend trips between Østerbro and Borup, both for weekend trips to Denmark/Skåne and for weekend trips outside Denmark/Skåne, the Østerbro sample shows higher shares in the high trip frequencies (3 trips or more within the last 12 months), whereas Borup shows higher shares for ‘no trips’ within the last 12 months.

The ordinal regression, however, shows that in both trip groups (weekend trips in Denmark/Skåne, outside Denmark/Skåne) education level and recent moving activity have significant effect on the number of trips (see Table 2). Respondents with a vocational or short-cycle higher education (1-2 years) go less frequently (Exp(B) = 0.438/0.434) on weekend trips than respondents with a medium- or long-cycle higher education. Changing the reference category for education level does not reveal a further statistically significant predictor value. Respondents who moved within the last five years go less frequently (Exp(B) = 0.548/0.53) on trips.

For weekend trips in Denmark/Skåne second home access and age also have significant effect (see Table 2). Respondents who have access to a second home – in Denmark typically a summer cottage in Denmark or Sweden – go more frequently (Exp(B) = 2.026) on weekend trips in Denmark/Skåne. This is also confirmed by the purpose the respondents name for their last weekend trip in Denmark/Skåne, which is after ‘family/family celebrations’ (approx. 30%) on the second rank ‘summer cottage’ with 20% in Østerbro and 14% in Borup. An increase in age (in years) is associated with a marginal decrease in the odds for more trips in Denmark/Skåne (Exp(B) = 0.962).
Table 2: Parameter estimates of the predictors with significant effect on number of weekend trips within the last 12 months; N=237.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Weekend trips in Denmark/Skåne</th>
<th></th>
<th>Weekend trips outside Denmark/Skåne</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>link function logit</td>
<td>Odds ratio Exp(B)</td>
<td>link function negloglog</td>
<td>Odds ratio Exp(B)</td>
</tr>
<tr>
<td>Age</td>
<td>-0.038</td>
<td>0.962 a</td>
<td>-0.017</td>
<td>0.983</td>
</tr>
<tr>
<td>Income per person per household (ln)</td>
<td>-0.065</td>
<td>0.937</td>
<td>0.86</td>
<td>2.364 a</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>-0.081</td>
<td>0.922</td>
<td>-0.42</td>
<td>0.657 a</td>
</tr>
<tr>
<td>male</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Workforce participation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>working</td>
<td>0.785</td>
<td>2.192</td>
<td>-1.165</td>
<td>0.312 a</td>
</tr>
<tr>
<td>in education</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Highest level of education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary or upper secondary</td>
<td>-0.626</td>
<td>0.535</td>
<td>-0.586</td>
<td>0.557</td>
</tr>
<tr>
<td>Vocational or short-cycle higher</td>
<td>-0.825</td>
<td>0.438 b,c</td>
<td>-0.835</td>
<td>0.434 b,c</td>
</tr>
<tr>
<td>Medium- or long-cycle higher</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Second home access</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>0.706</td>
<td>2.026 a</td>
<td>-0.223</td>
<td>0.8</td>
</tr>
<tr>
<td>no</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Moved within last 5 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>-0.602</td>
<td>0.548 a</td>
<td>-0.636</td>
<td>0.539 a</td>
</tr>
<tr>
<td>no</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction with housing density</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>satisfied</td>
<td>0.289</td>
<td>1.335</td>
<td>1.09</td>
<td>2.974 a,c</td>
</tr>
<tr>
<td>neither/nor</td>
<td>0.609</td>
<td>1.838</td>
<td>0.545</td>
<td>1.724</td>
</tr>
<tr>
<td>unsatisfied</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction with housing density (change of reference category)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unsatisfied</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neither/nor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>satisfied d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of significance: a p&lt;0.05; b p&lt;0.005; c overall test of statistical significance p&lt;0.05 for polytomous predictors; d change of reference category.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: This table includes only the predictors with significant effect on the dependent variable; the complete set of parameter estimates including also Std_Error and Wald is reported in the supplementary material.

Finally, income, gender and satisfaction with housing density have significant effect on the number of weekend trips outside Denmark/Skåne (see Table 2). An increase in income is associated with an increase in the odds for more trips (Exp(B) = 2.364). The effect of gender indicates that women go less frequently (Exp(B) = 0.657) on trips. This effect is remarkably stronger in the Borup sample than in the Østerbro sample as the respective trip frequencies show. Respondents who are unsatisfied or neither/unsatisfied/nor satisfied with the housing density of their living environment go less frequently (Exp(B) = 0.336/0.58) on weekend trips outside Denmark/Skåne than respondents who are satisfied, as shown by changing the reference category.
The effect of *workforce* on weekend trips outside Denmark/Skåne is in question due to a low number of respondents with no workforce participation. However, when excluding workforce from the model, the result is stable for the remaining predictors, but the model fit is better when keeping it in the model; *workforce* cannot be considered to add statistically significant value to the model.

The ordinal regression for the total number of weekend trips (tested with different aggregation modes) does not add further explanatory value to the study and is therefore not included.

### 4.2 Holiday trips

Comparing the total number of holiday trips between Østerbro and Borup, the Østerbro sample shows higher shares in the high trip frequencies (45% Østerbro vs. 21% in Borup did at least 3 trips within the last 12 months), whereas Borup shows higher shares in the lower trip frequencies (63% in Borup vs. 41% Østerbro). The share of ‘no trips’, with 14% in Østerbro and 16% in Borup, is almost equal.

When looking at holiday trips by destination the results reveal for Østerbro higher trip frequencies to Europe (30% in Østerbro vs. 44% in Borup made no trip to Europe) and outside Europe (71% in Østerbro vs. 79% in Borup made no trip outside Europe). For holiday trips to Denmark, the two populations show more or less equal shares.

However, separate ordinal regression models for holiday trips by destination did not achieve a good model fit or significance. We therefore focus on the results for the total number of holiday trips (aggregated trip frequencies per destination based on the lower limit of the respective frequency categories; significant predictors remain, also with alternative aggregation modes, unaffected).

The above-mentioned differences in trip numbers are confirmed by the ordinal regression, which shows that *residential location* and *education level* have significant effect on the number of holiday trips (see Table 3). Respondents *living in Østerbro* go more frequently (Exp(\(B\)) = 2.71) on holiday trips. Respondents with a vocational or short-cycle higher education (1-2 years) go, however, less frequently (Exp(\(B\)) = 0.359) on holiday trips than respondents with a medium- or long-cycle higher education. Changing the reference category for *education level* does not reveal a further statistically significant predictor value.

The predictors *satisfaction with availability of private green space* and *satisfaction with proximity to recreational areas, nature or green spaces* do not pass the overall test of statistical significance for polytomous predictors and do not therefore add statistically significant value to the model.
Table 3: Parameter estimates of the predictors with significant effect on total number of holiday trips within the last 12 months; N=227, link function logit.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Estimate</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Exp(β)</td>
</tr>
<tr>
<td>Highest level of education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary or upper secondary</td>
<td>-0.589</td>
<td>0.555</td>
</tr>
<tr>
<td>Vocational or short-cycle higher</td>
<td>-1.025</td>
<td>0.359b,c</td>
</tr>
<tr>
<td>Medium- or long-cycle higher</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Residential location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Østerbro</td>
<td>0.997</td>
<td>2.71a</td>
</tr>
<tr>
<td>Borup</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction with availability of private green space</td>
<td></td>
<td></td>
</tr>
<tr>
<td>satisfied</td>
<td>-0.79</td>
<td>0.454</td>
</tr>
<tr>
<td>neither/nor</td>
<td>-1.237</td>
<td>0.29a</td>
</tr>
<tr>
<td>unsatisfied</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction with proximity to recreational areas, nature or green spaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>satisfied</td>
<td>-2.526</td>
<td>0.08</td>
</tr>
<tr>
<td>neither/nor</td>
<td>-3.201</td>
<td>0.041a</td>
</tr>
<tr>
<td>unsatisfied</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Level of significance:  a p<0.05;  b p<0.005;  c overall test of statistical significance p<0.05 for polytomous predictors.

Note: This table includes only the predictors with significant effect on the dependent variable; the complete set of parameter estimates including also Std.Error and Wald is reported in the supplementary material.

The Mantel-Haenszel test of trend shows a statistically significant (p<0.005) association between total number of holiday trips and total number of weekend trips. A higher number of weekend trips is associated with a higher number of holiday trips and vice-versa.

4.3 Plane trips

Comparing the number of plane trips between Østerbro and Borup, the Østerbro sample shows a higher frequency of trips. In Østerbro, 74% of the sample have undertaken at least one private plane trip in the last 12 months, whereas in Borup, only 58% have undertaken at least one private plane trip.

This is also confirmed by the ordinal regression, which shows that residential location and education level have significant effect on the number of plane trips (see Table 4). Respondents living in Østerbro go more frequently (Exp(B) = 2.726) on plane trips. This is consistent with a higher number of holiday trips to more distant destinations (Europe, outside Europe) among the Østerbro sample. Respondents with a vocational or short-cycle higher education (1-2 years) go, however, less frequently (Exp(B) = 0.367) on plane trips than respondents with a medium- or long-cycle higher education. Changing the reference category for education level does not reveal a further statistically significant predictor value.

Changing the reference category for satisfaction with accessibility of public transport reveals that respondents who are neutral (neither satisfied nor unsatisfied) go less frequently (Exp(B) = 0.314) on plane trips than respondents who are satisfied (see Table 4). The share of respondents who are neutral is higher in Borup (13%) than in Østerbro (6%) which might be related to Borup’s lower number of plane trips.
Table 4: Parameter estimates of the predictors with significant effect on number of plane trips within the last 12 months; N=241, link function logit.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Estimate</th>
<th>Odds ratio Exp(β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest level of education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary or upper secondary</td>
<td>-0.405</td>
<td>0.667</td>
</tr>
<tr>
<td>Vocational or short-cycle higher</td>
<td>-1.002</td>
<td>0.367ab</td>
</tr>
<tr>
<td>Medium- or long-cycle higher</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Residential location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Østerbro</td>
<td>1.003</td>
<td>2.762a</td>
</tr>
<tr>
<td>Borup</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction with accessibility of public transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>satisfied</td>
<td>0.954</td>
<td>2.595</td>
</tr>
<tr>
<td>neither/nor</td>
<td>-0.203</td>
<td>0.816c</td>
</tr>
<tr>
<td>unsatisfied</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction with accessibility of public transport (change of reference category)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unsatisfied</td>
<td>-0.954</td>
<td>0.385</td>
</tr>
<tr>
<td>neither/nor</td>
<td>-1.157</td>
<td>0.314abc</td>
</tr>
<tr>
<td>satisfied</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Level of significance: a p<0.05; b p<0.005; c overall test of statistical significance p<0.05 for polytomous predictors; d change of reference category.

Note: This table includes only the predictors with significant effect on the dependent variable; the complete set of parameter estimates including also Std.Error and Wald is reported in the supplementary material.

5 Discussion: Are city dwellers compensating for compactness?

The results indicate that a combination of lifestyle, socio-economic factors and living environment (urban structure) explain the observed leisure travel behaviour. It shows higher frequencies in weekend and holiday trips as well as the use of air travel among the people living in the dense urban district of Østerbro. This becomes particularly evident as the odds for undertaking more holiday or plane trips are 2.7 times higher when living in Østerbro.

Compensating for compactness?

When looking at possible indications for compensatory behaviour, we identify a clear relationship between summer cottage/second home access and number of weekend trips to Denmark/Skåne. Considering that 47% of the Østerbro sample but only 22% of the Borup sample have access to a summer cottage, it appears that summer cottage access is some sort of compensation for the Østerbro dwellers’ need for ‘non-urbanity’. Our results deviate from those of Naess (2006) Copenhagen study regarding summer cottage access. However, our results are in line with findings from other previous studies on summer cottage use and ownership (e.g. Dijst et al., 2005; Strandell and Hall, 2015) and we can similarly describe the Østerbro dwellers’ summer cottage use as ‘escape’ (Dijst et al., 2005).

Our conclusion is further supported by the motives the respondents name for spending their free time in general: Among the respondents in Østerbro, who have access to a summer cottage, a high percentage names ‘fleeing from the city’ (39%) and ‘enjoying nature’ (46%) as important motives. In contrast, those without summer cottage access name, e.g., ‘visiting new places’ (54%) and ‘using the facilities of the city (e.g., shopping, culture, restaurants)’ (45%) as important motives. Considering the high number of summer cottages in Denmark (more than 220,000 in 2016) related to the country’s population...
of 5.7 million (Statistics Denmark, 2016) this kind of compensatory behaviour requires further attention.

For the number of holiday and plane trips the results show that living in Østerbro is a significant predictor for more trips. However, as we cannot identify a significant relationship between dissatisfaction of certain qualities of the living environment (e.g., access to green spaces, environmental quality) and more holiday or plane trips, we can hardly qualify these higher trip numbers as compensation. In contrast, for weekend trips outside Denmark/Skåne, respondents who indicate dissatisfaction about housing density undertake even fewer trips.

**Lifestyle and residential choice**

The results of our study suggest that particularly holiday and plane trips are rather an expression of a certain lifestyle or personal preferences than compensation for drawbacks of the living environment. This is in line with earlier explanations by Næss (2006, p. 216) who suggests that ‘an ‘urban’ and cosmopolitan lifestyle’ contributes to increased travelling. In general, studies show an increase in long-distance travel, which is explained by diverse reasons, such as impacts of globalisation, but also simply easy online booking options and competitive ticket prices (Kristensen et al., 2014; van Goeverden et al., 2016). A study on the fourth biggest Danish city, Aalborg, finds that in 2002 within 12 months only 20% of the sample went on either private or business related plane trips (Nielsen, 2002). Nielsen (2002) also proposed lifestyle factors as possible explanation, though, without further investigating them.

Our data shows a positive association between the total number of weekend and holiday trips; we interpret this that people are either travellers or not, which we consider as an expression of a certain lifestyle. Therefore, it appears that people with a certain lifestyle, e.g., who give travelling importance, simply prefer living in urban areas like Østerbro than in peri-urban areas. The respondents’ statements support this: 80% of the Østerbro sample (compared to only 61% of the Borup sample) state that ‘weekend trips and/or holiday trips are important to me’. On the other hand, people with a more family-oriented lifestyle might prefer living outside the big city.

Consequently, residential self-selection is a relevant factor for travel behaviour; people who like to travel possibly choose a residential location that easily allows travelling. However, also inversely may people – even if they have chosen to live in central urban locations such as Østerbro for other reasons – be stimulated to travel more due to low daily commuting expenses and ease of access to long-distance transport means such as an airport.

The significant difference in the number of plane trips between Østerbro and Borup (74% in Østerbro compared to only 58% in Borup have been on at least one private plane trip in the last 12 months) suggests that besides lifestyle factors, accessibility of an airport may be an important factor for undertaking plane trips (see Bruderer Enzler, 2017). The results confirm that respondents who are neither satisfied nor unsatisfied with access to public transport undertake fewer plane trips.

The study shows that respondents who moved within the last five years went on fewer weekend trips, both in and outside Denmark/Skåne, and the most frequently named reasons for moving (or planning to move) are ‘size/quality of the living space’ and ‘change of family situation’. Moving seems to indicate an adjustment of the residential location to lifestyle-related preferences; but also, moving or a change in the family situation can imply less disposable income and/or time for travelling.
The impact of socio-economic factors

Finally, socio-economic factors play a role, which is, however, limited in our study due to the purposefully chosen case areas that represent rather balanced socio-economic profiles (predominantly workforce participation, balanced income, etc.). However, education level turns out as a significant predictor in all trip types (weekend / holiday / plane trips): Respondents with lower education (vocational or short-cycle higher education (1-2 years)) go less frequently on trips than respondents with a medium- or long-cycle higher education.

Furthermore, respondents with higher income go more frequently on weekend trips outside of Denmark/Skåne, which seems obvious, as those trips most likely require taking an expensive plane. However, income is not a significant predictor when looking at plane trips separately.

Moreover, we found a relation between education level and summer cottage access. In the Østerbro sample, there is almost no difference in the distribution of education level between respondents with access to a summer cottage and those without access, which supports the argument of the summer cottage as compensation. However, in the Borup sample, 85% of the respondents with summer cottage access fall in the highest education level category (medium- or long cycle higher education), whereas only 49% of the respondents without summer cottage access fall in this category; thus, summer cottage access in Borup appears to be more related to lifestyle.

Limitations of the study

The results of the ordinal regression models allow for some evident conclusions, however, some explanations of the observed phenomena are based on educated deduction and are worth following up in more detail in further research, especially those related to lifestyle and residential choice. The gaps in final and conclusive explanations result to some extent from difficulties in determining the complexities of behaviour-related phenomena and to some extent from limitations in the data and statistical analysis, due to a limited number of survey responses and some incomplete responses. However, the results allow for some very relevant conclusions that provide an important contribution to the discussion on compensatory leisure travel.

6 Conclusions

This study on Greater Copenhagen shows that city dwellers (Østerbro) go more frequently on weekend, holiday and plane trips and also choose more distant destinations (weekend trips outside of Denmark/Skåne, holiday trips outside Denmark and outside Europe) than small town dwellers (Borup).

Overall, when looking for reasons for the observed leisure travel behaviour, lifestyle-related factors (to some extent combined with socio-economic factors) and corresponding residential choices appear to be stronger determinants than compensation. The results indicate that people with a certain lifestyle, which might include the wish to travel, choose to live in central urban rather than peri-urban locations.

However, access to a summer cottage or second home plays an important role and can be considered as some sort of compensation of city dwellers, but it is also a residential choice that may not always be necessarily driven by compensation.

This melange of causes and their interactions, which result in a certain outcome of leisure travel, challenges the role of urban planning: Is there a need for urban planning to intervene? If yes, what possibilities does urban planning have for intervening?
The results reveal two main focus points: First, a significantly higher number of – environmentally harmful – plane trips among city dwellers; second, city dwellers seem to compensate their urban living environment to a certain extent with access to a summer cottage related to more weekend trips.

Holiday and plane trips are, as the study shows, possibly driven by lifestyle factors going along with residential choices. However, increasing the prices of plane tickets, which could be an effective measure, is beyond the scope of urban planning.

The role of the summer cottage, particularly with respect to its importance in the Danish context, could rather be in the focus of urban planning. One relevant aspect is housing affordability in Copenhagen and in general in big cities. Currently, access to a private garden near the house or bigger living spaces are hardly affordable for the majority of the city population. Improving access to such higher living standards (EEA, 2015) might to some extent counteract the need for a summer cottage and related weekend trips. However, it is questionable whether even very high urban liveability in terms of, e.g., access to green spaces – as we find them partly in Østerbro – could outweigh the attractiveness of a summer cottage. A different path concerns improving the accessibility of summer cottages and the sustainability of their locations through, e.g., better connections by public transport and increased energy efficiency of the summer cottage settlements.

Finally, related planning decisions affect the trade-off between more sustainable daily life in the city but possibly more extensive leisure travel on the one hand, and less sustainable daily life in peri-urban areas but less extensive leisure travel on the other hand. Planning decisions therefore require stronger input on the factual impacts of travel behaviour, i.e. whether the environmental advantages of city life outweigh the negative impacts of its rebound effects?

This implies, firstly, giving leisure travel more importance in urban development agendas and, accordingly, more concern with regard to people’s residential choices (self-selection). Secondly, further research is needed to investigate the role of indirect energy consumption (e.g., consumption of goods and services) in the discourse of urban structure related rebound effects, which have again a lifestyle-related dimension. Our study highlights the importance of lifestyle for people’s behaviour and thereby emphasises the need to consider more strongly the role of lifestyle in policy-making and planning decisions. This calls for discussing the possibilities of urban planning to address lifestyle, but possibly also demonstrates limitations of urban planning in certain questions of policy-making.

Acknowledgements

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Conflicts of interest

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Appendix - Survey questions for dependent variables

In the last 12 months, how many times have you been on a weekend trip ... (only trips with max. 3 overnight stays, we ask for longer holidays later) *(single choice)*

<table>
<thead>
<tr>
<th></th>
<th>12 times or more</th>
<th>6-11 times</th>
<th>3-5 times</th>
<th>1-2 times</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>... in Denmark or Skåne (more than 30 km outbound distance from home)?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>... outside of Denmark or Skåne?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

In the last 12 months, how many times have you been on holidays (at least 4 overnight stays) ... *(single choice)*

<table>
<thead>
<tr>
<th></th>
<th>More than 5 times</th>
<th>3-5 times</th>
<th>1-2 times</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>on Zealand?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>elsewhere in Denmark?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>elsewhere in Scandinavia?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>elsewhere in Europe?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>outside of Europe?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

In the last 12 months, for how many private trips (weekend trips, holidays, ...) have you in total used a plane? *(single choice)*

- ☐ Never
- ☐ 1-2 trips
- ☐ 3-5 trips
- ☐ 6-10 trips
- ☐ More than 10 trips
- ☐ Don’t know.
### Supplementary material / Paper IV

#### Weekend trips in DK/Skåne / logit

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>Wald</th>
<th>Sign.</th>
<th>p</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold (weekendtrips in DK = 0)</td>
<td>3.820</td>
<td>4.757</td>
<td>0.645</td>
<td>0.412</td>
<td>0.276</td>
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<tr>
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<td>-2.021</td>
<td>4.752</td>
<td>0.181</td>
<td>0.671</td>
<td>1.055</td>
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<td></td>
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<tr>
<td>Threshold (weekendtrips in DK = 3)</td>
<td>0.885</td>
<td>4.751</td>
<td>0.033</td>
<td>0.852</td>
<td>0.176</td>
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</tr>
<tr>
<td><strong>Predictor</strong></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td><strong>age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Income per person</td>
<td>-0.038</td>
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<td>5.561</td>
<td>0.018</td>
<td>0.962</td>
<td>0.932</td>
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<td>0.113</td>
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<td>1.051</td>
<td>0.843</td>
<td>1.310</td>
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<td>0.078</td>
<td>0.781</td>
<td>0.88</td>
<td>0.358</td>
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<td>0.477</td>
<td>0.484</td>
<td>0.487</td>
<td>1.37</td>
<td>0.564</td>
<td>3.328</td>
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<tr>
<td>Family type=couple, no children</td>
<td>0.539</td>
<td>0.45</td>
<td>1.745</td>
<td>0.186</td>
<td>1.715</td>
<td>0.770</td>
<td>3.816</td>
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<td>0.772</td>
<td>0.922</td>
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<td>0.785</td>
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<td>1.146</td>
<td>0.284</td>
<td>2.192</td>
<td>0.521</td>
<td>9.222</td>
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<td>Workforce=in education</td>
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<td>Education-level=Primary or upper secondary</td>
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<td>1.782</td>
<td>0.182</td>
<td>0.535</td>
<td>0.213</td>
<td>1.341</td>
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<td>0.311</td>
<td>7.144</td>
<td>0.008</td>
<td>0.438</td>
<td>0.239</td>
<td>0.802 *</td>
</tr>
<tr>
<td>Education-level=Medium- or long-cycle higher</td>
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<td>1.009</td>
<td>0.315</td>
<td>0.627</td>
<td>0.252</td>
<td>1.559</td>
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<td>Car ownership=1 car</td>
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<td>0.886</td>
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<td>0.718</td>
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<td>Car ownership=2 or more cars</td>
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<tr>
<td>Garden type=no garden</td>
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<td>0.407</td>
<td>0.555</td>
<td>0.456</td>
<td>0.739</td>
<td>0.333</td>
<td>1.639</td>
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<tr>
<td>Garden type=priv. garden at house/in town</td>
<td>-0.582</td>
<td>0.487</td>
<td>1.435</td>
<td>0.231</td>
<td>0.559</td>
<td>0.216</td>
<td>1.448</td>
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<tr>
<td>Garden type=shared garden at house</td>
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<tr>
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<td>0.706</td>
<td>0.274</td>
<td>6.667</td>
<td>0.01</td>
<td>2.026</td>
<td>1.185</td>
<td>3.461</td>
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<tr>
<td>Second home access=no</td>
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<tr>
<td>Moved within last 5 years=yes</td>
<td>-0.602</td>
<td>0.308</td>
<td>3.963</td>
<td>0.047</td>
<td>0.548</td>
<td>0.303</td>
<td>0.991</td>
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<tr>
<td>Moved within last 5 years=no</td>
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<tr>
<td>Availability of private green space=satisfied</td>
<td>-0.083</td>
<td>0.525</td>
<td>0.025</td>
<td>0.874</td>
<td>0.92</td>
<td>0.330</td>
<td>2.570</td>
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<tr>
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<td>0.236</td>
<td>0.557</td>
<td>0.18</td>
<td>0.671</td>
<td>1.266</td>
<td>0.426</td>
<td>3.762</td>
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<tr>
<td>Proximity to recreational areas, nature or green spaces=satisfied</td>
<td>0.595</td>
<td>1.057</td>
<td>0.319</td>
<td>0.572</td>
<td>1.813</td>
<td>0.230</td>
<td>14.325</td>
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<td>1.176</td>
<td>0.668</td>
<td>0.414</td>
<td>2.607</td>
<td>0.262</td>
<td>25.913</td>
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<td>0</td>
<td>0.027</td>
<td>0.456</td>
<td>0.004</td>
<td>0.953</td>
<td>1.027</td>
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<tr>
<td>Environmental quality=satisfied</td>
<td>0.305</td>
<td>0.486</td>
<td>0.397</td>
<td>0.529</td>
<td>1.357</td>
<td>0.525</td>
<td>3.509</td>
</tr>
<tr>
<td>Environmental quality=neither/nor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental quality=unsatisfied</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Housing density=satisfied</td>
<td>0.289</td>
<td>0.477</td>
<td>0.369</td>
<td>0.543</td>
<td>1.335</td>
<td>0.526</td>
<td>3.386</td>
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<tr>
<td>Housing density=neither/nor</td>
<td>0.609</td>
<td>0.516</td>
<td>1.396</td>
<td>0.237</td>
<td>1.838</td>
<td>0.670</td>
<td>5.046</td>
</tr>
<tr>
<td>Housing density=unsatisfied</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility of public transport=satisfied</td>
<td>-0.424</td>
<td>0.538</td>
<td>0.622</td>
<td>0.43</td>
<td>0.655</td>
<td>0.228</td>
<td>1.877</td>
</tr>
<tr>
<td>Accessibility of public transport=neither/nor</td>
<td>-0.31</td>
<td>0.641</td>
<td>0.234</td>
<td>0.629</td>
<td>0.734</td>
<td>0.209</td>
<td>2.573</td>
</tr>
<tr>
<td>Accessibility of public transport=unsatisfied</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

* overall test of statistical significance p <0.05 for polytomous predictors

N = 237

Model fit (likelihood ratio) p <0.05
### Supplementary Material / Paper IV

#### Weekend Trips Outside DK/Skåne / Negloglog

<table>
<thead>
<tr>
<th>predictor</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>Wald</th>
<th>Sign. p</th>
<th>Exp(β)</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold [weekendtrips_outsideDK + 0]</strong></td>
<td>7.865</td>
<td>3.649</td>
<td>4.646</td>
<td>0.031</td>
<td>9.092</td>
<td>1.007</td>
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</tr>
<tr>
<td><strong>Threshold [weekendtrips_outsideDK + 1]</strong></td>
<td>9.433</td>
<td>3.659</td>
<td>6.647</td>
<td>0.010</td>
<td>11.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>-0.017</td>
<td>0.013</td>
<td>1.863</td>
<td>0.172</td>
<td>0.983</td>
<td>0.095</td>
<td>1.077</td>
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<tr>
<td>ln_income_per_person</td>
<td>0.86</td>
<td>0.321</td>
<td>7.161</td>
<td>0.007</td>
<td>2.364</td>
<td>1.259</td>
<td>4.348</td>
</tr>
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<td>ln_distance_to_workplace</td>
<td>-0.117</td>
<td>0.083</td>
<td>1.994</td>
<td>0.158</td>
<td>0.89</td>
<td>0.756</td>
<td>1.046</td>
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<tr>
<td>family_type= single</td>
<td>-0.211</td>
<td>0.345</td>
<td>0.374</td>
<td>0.541</td>
<td>0.81</td>
<td>0.412</td>
<td>1.592</td>
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<td>family_type= single, ≥1 child</td>
<td>0.16</td>
<td>0.341</td>
<td>0.22</td>
<td>0.639</td>
<td>1.173</td>
<td>0.602</td>
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<td>family_type= couple, no children</td>
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<td>0.314</td>
<td>0.83</td>
<td>0.362</td>
<td>0.751</td>
<td>0.406</td>
<td>1.390</td>
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<tr>
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<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>gender=female</td>
<td>-0.42</td>
<td>0.212</td>
<td>3.914</td>
<td>0.048</td>
<td>0.657</td>
<td>0.433</td>
<td>0.996</td>
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<tr>
<td>gender= male</td>
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<td>1</td>
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<tr>
<td>workforce=working</td>
<td>-1.165</td>
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<td>4.23</td>
<td>0.04</td>
<td>0.312</td>
<td>0.103</td>
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<td>1</td>
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<tr>
<td>education_level=Primary or upper secondary</td>
<td>-0.586</td>
<td>0.389</td>
<td>2.265</td>
<td>0.132</td>
<td>0.557</td>
<td>0.260</td>
<td>1.194</td>
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<tr>
<td>education_level=Vocational or short-cycle higher</td>
<td>-0.835</td>
<td>0.255</td>
<td>10.69</td>
<td>0.001</td>
<td>0.434</td>
<td>0.263</td>
<td>0.716*</td>
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<td>1</td>
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<tr>
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<td>0.351</td>
<td>0.388</td>
<td>0.533</td>
<td>0.803</td>
<td>0.404</td>
<td>1.599</td>
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<td>car_ownership=1 car</td>
<td>-0.214</td>
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<td>0.646</td>
<td>0.422</td>
<td>0.807</td>
<td>0.479</td>
<td>1.361</td>
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<td>1</td>
<td></td>
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<tr>
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<td>-0.261</td>
<td>0.283</td>
<td>0.85</td>
<td>0.357</td>
<td>0.77</td>
<td>0.442</td>
<td>1.342</td>
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<td>2.029</td>
<td>0.154</td>
<td>0.604</td>
<td>0.301</td>
<td>1.209</td>
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<td>0</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
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<td>0.201</td>
<td>1.234</td>
<td>0.267</td>
<td>0.8</td>
<td>0.540</td>
<td>1.186</td>
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<td>1</td>
<td></td>
<td>1</td>
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<tr>
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<td>-0.636</td>
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<td>6.482</td>
<td>0.011</td>
<td>0.53</td>
<td>0.325</td>
<td>0.864</td>
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<tr>
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<td>0</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of private green space=satisfied</td>
<td>-0.296</td>
<td>0.368</td>
<td>0.646</td>
<td>0.422</td>
<td>0.744</td>
<td>0.361</td>
<td>1.531</td>
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<tr>
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<td>-0.164</td>
<td>0.39</td>
<td>0.178</td>
<td>0.673</td>
<td>0.848</td>
<td>0.395</td>
<td>1.822</td>
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<tr>
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<td>-0.408</td>
<td>0.764</td>
<td>0.285</td>
<td>0.593</td>
<td>0.665</td>
<td>0.149</td>
<td>2.973</td>
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<tr>
<td>Proximity to recreational areas, nature or green spaces=neither/or</td>
<td>0.182</td>
<td>0.843</td>
<td>0.047</td>
<td>0.829</td>
<td>1.2</td>
<td>0.230</td>
<td>6.256</td>
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<tr>
<td>Proximity to recreational areas, nature or green spaces=unsatisfied</td>
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<td>1</td>
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<td>1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Environmental quality=satisfied</td>
<td>-0.043</td>
<td>0.339</td>
<td>0.016</td>
<td>0.899</td>
<td>0.958</td>
<td>0.492</td>
<td>1.863</td>
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* overall test of statistical significance p < 0.05 for polytomous predictors
** change of reference category

N = 237
Model fit (likelihood ratio) p < 0.05
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<th>Sign. p</th>
<th>Exp(β)</th>
<th>95% CI Lower</th>
<th>Upper</th>
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* overall test of statistical significance $p < 0.05$ for polytomous predictors

N = 227
Model fit (likelihood ratio) $p < 0.05$
### Supplementary material / Paper IV

#### plane trips total / logit

<table>
<thead>
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<th>Exp(β)</th>
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<td>Environmental quality=satisfied</td>
<td>-0.074</td>
<td>0.476</td>
<td>0.024</td>
<td>0.877</td>
<td>0.929</td>
<td>0.211</td>
<td>0.929</td>
</tr>
<tr>
<td>Environmental quality=neither/nor</td>
<td>-0.723</td>
<td>0.502</td>
<td>2.072</td>
<td>0.15</td>
<td>0.485</td>
<td>0.181</td>
<td>1.299</td>
</tr>
<tr>
<td>Environmental quality=unsatisfied</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Housing density=satisfied</td>
<td>0.932</td>
<td>0.516</td>
<td>3.256</td>
<td>0.071</td>
<td>2.539</td>
<td>0.923</td>
<td>7.330</td>
</tr>
<tr>
<td>Housing density=neither/nor</td>
<td>0.896</td>
<td>0.556</td>
<td>2.601</td>
<td>0.107</td>
<td>2.451</td>
<td>0.825</td>
<td>7.726</td>
</tr>
<tr>
<td>Housing density=unsatisfied</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Accessibility of public transport=satisfied</td>
<td>0.954</td>
<td>0.583</td>
<td>2.675</td>
<td>0.102</td>
<td>2.595</td>
<td>0.828</td>
<td>8.528</td>
</tr>
<tr>
<td>Accessibility of public transport=neither/nor</td>
<td>-0.203</td>
<td>0.691</td>
<td>0.087</td>
<td>0.768</td>
<td>0.816</td>
<td>0.211</td>
<td>3.839</td>
</tr>
<tr>
<td>Accessibility of public transport=unsatisfied</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* overall test of statistical significance p <0.05 for polytomous predictors
** change of reference category

N = 241
Model fit (likelihood-ratio) p <0.05
Appendix – Questionnaire (English version)

The questionnaire was provided in English and Danish.
Thank you for participating in this survey!
My name is Juliane Große and I am PhD student at the University of Copenhagen. The aim of the survey is to understand, how people's travel behaviour in daily life, free time and on holidays relates to the living environment. By filling in this survey you contribute to gaining knowledge on how towns and cities can become more energy efficient in the future, and moreover about people's preferences and wishes for urban development. Your answers matter, regardless if you travel a lot or only little. It takes about 20 minutes to complete the survey.

You will be asked about your travel behaviour, your attitudes and expectations towards, for instance, car use, free time activities and holidays, your background, age, gender, education etc. and your satisfaction with home and living environment. Your answers will be anonymous and all information will be handled confidentially. If you have questions or experience problems with the survey, please don't hesitate to contact me via jj@ign.ku.dk or phone 26919434.

Thank you very much in advance!
Kind regards
Juliane Große

You can read more about my work here: http://research.ku.dk/search/?pure=en/persons/473991

To start off, we first have some questions about yourself

1. What is your gender?
   - Female
   - Male

2. What is your year of birth?
   ________

3. What is your current employment status?
   - Employed full-time
   - Employed part-time
   - Self-employed
   - Co-working spouse
   - On leave
   - Unemployed
   - In education
   - Retired / early retirement
   - Other: ________

We will now ask some questions about your car use in general:

4. Do you hold a driving license?
   - Yes
   - No

5. How many passenger cars does your household hold? (incl. company car for private use)
   - None
   - 1
   - 2
   - 3 or more

6. What type of passenger car(s) does your household hold? (check multiple boxes if you hold different types)
   - Petrol
   - Diesel
   - Hybrid
   - Electric
   - Other: ________

7. Think of a typical week (Monday to Sunday), how many days per week do you use the car, alone or shared with others?
   - 0 days
   - 1-2 days
   - 3-5 days
   - 6-7 days

8. Think of a typical week, how many car journeys do you undertake during the weekdays and at the weekend? (one journey is considered as the whole travel - from home and back to home)
   Total number of car journeys during the weekdays (Monday to Friday) ________
   Total number of car journeys at the weekend (Saturday and Sunday) ________
9. Think of a typical week (Monday to Sunday), how often do you use the car for the following activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>0 days</th>
<th>1-2 days</th>
<th>3-5 days</th>
<th>6-7 days</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commute to work/education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For/during work (during working time)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Escort kids to school/day care</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Escort kids to friends and leisure activities (e.g. sports, club, music school)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own leisure activities during the week or at weekends</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shopping, grocery, doctor’s consultation, hairdresser</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visit family/friends</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other ...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. What "other" activity were you thinking of?

11. Think about last week (past 7 days), how many kilometres did you travel in your car?

<table>
<thead>
<tr>
<th>Distance</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-20 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-50 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51-100 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101-200 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 200 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don't know</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

12. What share of kilometres was related to work/education (incl. commuting)?

<table>
<thead>
<tr>
<th>Share</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-25%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26-50%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51-75%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don't know</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

13. To what extent do you need a car to fulfill your daily activities (e.g. commute, escort kids, leisure, shopping)?

<table>
<thead>
<tr>
<th>Need for car</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I cannot fulfill my daily activities without a car.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is difficult to fulfill my daily activities without a car.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have other more or less equal options (public transport, bicycle etc.).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can easily fulfill my daily activities without a car.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I almost don’t use the car.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: _________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. During the past 12 months, did you rent a car, use car pools or car sharing?

<table>
<thead>
<tr>
<th>Use of car</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. For which purposes did you rent a car, or use car pools/car sharing?

<table>
<thead>
<tr>
<th>Purpose</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Go to the summer house</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekend trips</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport of goods / moving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holidays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: _________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We will now ask some questions about your daily travel routines. Please think about your routines in a typical week (Monday to Sunday).

16. Where is your workplace or educational institution located? (choose most frequent one if multiple work/educational locations)

<table>
<thead>
<tr>
<th>Location</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In Østerbro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elsewhere in Copenhagen or Frederiksberg municipality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Copenhagen region (Hovedstadsområdet), approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In another town in Zealand, approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In another town in Denmark, approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abroad, approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. Where is your workplace or educational institution located? (choose most frequent one if multiple work/educational locations)

<table>
<thead>
<tr>
<th>Location</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In Borup</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Copenhagen or Frederiksberg municipality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Copenhagen region (Hovedstadsområdet), approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In another town in Zealand, approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In another town in Denmark, approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abroad, approx. distance in km from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
17. How do you mostly get to work or education? (check multiple boxes when combining transport modes in one journey)
- I work from home / stay at home
- Walking
- Cycling
- E-biking
- Motorbike / moped
- Private car
- Car pool
- Company car
- Public transport (bus, train, s-train, metro)
- Airplane
- Other ...

18. Please select the main reasons for the choice of your transport mode to work/education (select max. 3):
- It is fast
- It is easily accessible
- It is flexible
- It is convenient
- It is cheap
- My employer provides the car
- I have problems with my health
- I have a lot of stuff to carry
- I have to escort my kids/grandchildren
- It is healthy
- It is good for the environment
- It is the only choice
- Other ...

We will now ask you about how you spend your free time during the week and at weekends. Please think about your routines in general during the year.

19. How often do you undertake the following activities in your free time?

- House maintenance (repairs, cleaning etc.)
- Spending time in the garden (leisure, gardening)
- Walking, running, bicycle trip or other outdoor activities/sports
- Practicing indoor sports, hobbies or leisure-time education (music, language courses etc.)
- Culture/entertainment (cinema, theatre, museum, restaurant, sports event etc.)
- Shopping (excl. grocery or daily needs)
- Visiting family or friends at their home
- Going to a park or outdoor area (e.g. forest, lake) in my town or nearby
- Trips further away from my town

20. In a typical week (Monday to Sunday), how much time do you spend in total to travel to your free time activities?
- Less than 1 hour
- 1-3 hours
- 3-5 hours
- 5-10 hours
- More than 10 hours
- Don't know

21. Think of a typical week (Monday to Sunday), how do you mostly get to your free time activities? (check multiple boxes if you use different ones for different activities)
- Walking
- Cycling
- E-biking
- Motorbike / moped
- Private car
- Car pool
- Company car
- Public transport (bus, train, s-train, metro)
- Airplane
- Other ...

22. Please select the main reasons for the choice of your transport mode to free time activities (select max. 3):
- It is fast
- It is easily accessible
- It is flexible
- It is convenient
- It is cheap
- My employer provides the car
- I have problems with my health
23. In the last 12 months, how many times have you been on a weekend trip ...
(only trips with max. 3 overnight stays; we ask for longer holidays later)

   ... in Denmark or Skåne (more than 30 km outbound distance from home)?
   ... outside of Denmark or Skåne?

24. Think of your last weekend trip, when (date) and how far (distance) was it?

   Approx. outbound distance in km

<table>
<thead>
<tr>
<th>Date (e.g. “January 2016”)</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>June</td>
<td>July</td>
</tr>
<tr>
<td>August</td>
<td>September</td>
<td>October</td>
</tr>
<tr>
<td>November</td>
<td>December</td>
<td>January</td>
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<tr>
<td>February</td>
<td>March</td>
<td>April</td>
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<tr>
<td>May</td>
<td>June</td>
<td>July</td>
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<tr>
<td>August</td>
<td>September</td>
<td>October</td>
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<tr>
<td>November</td>
<td>December</td>
<td>January</td>
</tr>
<tr>
<td>February</td>
<td>March</td>
<td>April</td>
</tr>
</tbody>
</table>

   To Denmark or Skåne (more than 30 km outbound distance from home)?
   Outside of Denmark or Skåne?

25. For which activity/ies or purpose/s did you go on your last weekend trip ...

   ... in Denmark or Skåne (more than 30 km outbound distance from home)?
   ... outside of Denmark or Skåne?

26. How (transport mode) did you get to the destination of your last weekend trip ...
(check multiple boxes if you combined transport modes in one journey)

   ... in Denmark or Skåne (more than 30 km outbound distance from home)?
   ... outside of Denmark or Skåne?

Now, we will ask you about how you spend your holidays; think of trips with at least 4 overnight stays:

27. In the last 12 months, how many times have you been on holidays (at least 4 overnight stays) ...

   More than 5 times  3-5 times  1-2 times  Never

   on Zealand?
   elsewhere in Denmark?
   elsewhere in Scandinavia?
   elsewhere in Europe?
   outside of Europe?

28. In the last 12 months, for going on holidays, which transport modes did you use?
(only for journey to/from holiday destination)

   More than 5 times  3-5 times  1-2 times  Never

   Car (private or rental)
   Ferry
   Train or bus
   Plane
   Other

29. What "other" transport mode did you use?

   ...

30. In the last 12 months, for how many private trips (weekend trips, holidays, ...) have you in total used a plane?

   Never  1-2 trips  3-5 trips  6-10 trips  More than 10 trips  Don’t know.

31. Think about all your free time activities, trips and holidays - after work, at weekends and on holidays:
I spend my free time as described because ...
(select max. 3)

   I want to “flee” from the city
   I prefer to practice my outdoor activities outside the city/town in green surroundings
   I want to enjoy nature
   I want to spend time with my family
   I want to live healthy
   I have no access to green spaces close to where I live
   I like to use the facilities of the city (e.g. shopping, culture, restaurants)
   I want to develop my skills / continuing education
   I like to visit new places
   Other:
Finally, we’d like to ask you about your home and your living environment:

32. In what type of housing do you live most of the year?

- Detached single-family house/farmhouse
- Terraced house, linked house or semi-detached house
- Block of flats
- Summer house, second home or allotment garden house
- Student residence
- Other: __________

33. Do you have access to a garden? (own or share)

- Yes
- No

34. What kind of garden?

- Private garden attached to my house
- Shared garden of my house community (e.g. back yard)
- Private garden in another part of my town (e.g. allotment garden)
- Private garden in another town (e.g. allotment garden), approx. distance in km from home __________
- Other: __________

35. Do you have access to a summer house, second home or allotment garden house for overnight stay? (own or share)

- Yes
- No

36. How far from your home is the summer house or second home located?

approx. km __________

37. In the last 12 months, how many times did you go there?

<table>
<thead>
<tr>
<th>In the spring/summer season</th>
<th>Several weeks/months</th>
<th>More than once a week</th>
<th>Once a week</th>
<th>2-3 times a month</th>
<th>Once a month</th>
<th>Several times a year</th>
<th>Once a year</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the autumn/winter season</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

38. How satisfied are you with the following qualities of your home and your living environment?

- Affordable/price
- Size and/or quality of living space
- Availability of private green space (e.g. garden)
- Proximity to recreational areas, nature or green spaces
- Environmental quality (e.g. noise, pollution)
- Housing density
- Proximity to everyday facilities (e.g. school/Kindergarten, grocery, doctor etc.)
- Proximity to workplace/place of education
- Accessibility of public transport
- Proximity to family or friends
- Location of my home in general
- Overall satisfaction with home and living environment

39. Did you move within the last 5 years?

- Yes
- No, but I plan to move within the next year.
- No

40. Where did you live (Danish ZIP code or foreign municipality) before you moved here?

____________

41. Why did you move/plan to move? Please select your main reasons:

- Affordable/price
- Size and/or quality of living space
- Access to a private garden
- Live closer to nature and/or higher environmental quality (e.g. noise, pollution)
- Live more central / closer to everyday facilities (e.g. school, day care, shopping, doctor)
- Change of workplace/place of education
- Transport options / accessible transport modes
- Close to family
- Change of family situation (e.g. got kids, married, divorced)
- Inherited the house
- Change of living environment in general
- I am/was forced to move (e.g. limited rental contract)
- Other: __________

42. Did you sell or buy a car since you moved?
43. Did your travel behaviour change since you moved, with regard to ...

- travel to work/education?
- free time travel (after work, weekend etc. - without overnight stay)?

44. Did the frequency of your free time activities change since you moved?

- House maintenance (repairs, cleaning etc.), spending time in the garden (leisure, gardening)
- Going to a park or outdoor area in my town or nearby (e.g. walking, running, bicycle trip or other outdoor activities)
- Trips further away from my town (without overnight stay)
- Weekend trips
- Holidays (at least 4 overnight stays)

45. Please select the main reasons for changing your travel behaviour and/or your free time activities? (select max. 3)
- Change of workplace/place of education or change of commuting distance
- Change in disposable income
- Changed leisure habits
- Change in transport prices (e.g. petrol, ticket prices for bus, train or airplane)
- Change of offer/alternatives in transport modes (e.g. accessibility, speed, comfort)
- Change of lifestyle (health, environmental friendliness etc.)
- Access to a garden or nearby green space
- Got car / sold car
- Change of family situation (e.g. got kids, married, divorced)
- Other ...

Before we get to the last questions about you, we are interested how much you agree or disagree on the following statements:

46. Please grade to what extent you agree or disagree with the following statements:

I like living in the city.
I try to spend as much time as possible in the nature in my free time.
Weekend trips and/or holidays are important for me.
It is important for me that my transport mode in daily life is environmentally friendly.
It is important for me that my transport mode to weekend trips and holidays is environmentally friendly.
I can travel more in my free time because I have a quick and cheap way to work/education.
My fixed expenses leave only little scope to go on weekend trips and/or holidays.
I am fine with living in the city with less access to green spaces because I have in return short daily travel distances.
I would like to move out of the city to a greener environment.
If I would live in a greener environment, I would travel less in my free time and spend more time in the garden or the surrounding nature.
Owning a car gives me freedom to go where- and whenever I want.

46. Please grade to what extent you agree or disagree with the following statements:

I like living outside Copenhagen in a small town.
As I live close to nature/green environment I don’t often go on trips and/or holidays in my free time.
Weekend trips and/or holidays are important for me.
It is important for me that my transport mode in daily life is environmentally friendly.
It is important for me that my transport mode to weekend trips and holidays is environmentally friendly.
My way to work/education takes a lot of time, therefore I don’t have so much free time.
My fixed expenses leave only little scope to go on weekend trips and/or holidays.
I am fine with having a longer travel distance to work/education because I live in return in more green surroundings.
I would like to move in order to live more central.
If I would live in the city, I would travel more in my free time.
Owning a car gives me freedom to go where- and whenever I want.

Finally, we need some personal information about you; it will be handled confidentially and used only for research purposes:

47. What is your highest education level?
- Primary education (7-10th grade)
- Upper secondary education (high school, gymnasium)
- Vocational education / technical school
- Short-cycle higher education (1-2 years, e.g. some college, laboratory technician)
- Medium-cycle higher education (2-4 years, e.g. Bachelor, nursing school)
- Long-cycle higher education (more than 4 years, e.g. Master)
- Other ...

48. Including yourself, how many people live in your household?
49. How many of the household members are under 18 years old?
- None
- 1
- 2
- 3
- 4 or more

50. What is the total income (before-tax) of your household per year?
- Less than 200,000 DKK
- 200,000 - 299,999 DKK
- 300,000 - 399,999 DKK
- 400,000 - 499,999 DKK
- 500,000 - 599,999 DKK
- 600,000 - 699,999 DKK
- 700,000 - 799,999 DKK
- 800,000 - 899,999 DKK
- 900,000 - 999,999 DKK
- 1,000,000 DKK and more
- Don’t know
- Don’t want to answer

Thank you very much for your response. If you have any further comments you are welcome to add something here:

Thank you very much for your help!

Read more about the research project on www.urbanenergyresearch.com

REMEMBER to submit your answers with the ‘Finish’-button.
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PhD Thesis September 2017

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Urban structure and sustainable transport