Environmentally Significant Behaviour: Spatial Distribution, Drivers, and Barriers to Change

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Dissertation submitted in partial fulfillment of a
Philosophiae Doctor degree in Environmental Studies

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Green Actions: Urban Form, Drivers and Barriers
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Abstract

The consumption activities of urbanites contribute to an ever-increasing share of greenhouse gas emissions and resource depletion. As urban form influences behaviours, the search for the most sustainable type of urban form is a research topic of interest. The compact city is widely regarded as the most environmentally friendly form, due to lower local travel emissions and more efficient housing energy. Yet, research has shown that the connection is a lot more complex. While attitudes play a role in pro-environmental behaviours, the existence of an attitude-behaviour gap complicates the connection. This thesis explores the spatial characteristics, drivers, and barriers to change of environmentally significant behaviours, with a special focus on air travel. It utilizes mixed-methods to dive deeper into motivations, justifications, and previously unidentified drivers. High international and low local travel emissions clustered in city centers, and while pro-environmental attitudes affected pro-environmental behaviours related to produce, clothing, and energy use, they did not affect travel emissions. In addition to the residential location, drivers of local travel emissions included pro-car attitudes and suburban dwelling preferences, while a hectic urban life and lack of green areas drove domestic travel. One of the main drivers of international travel emissions was cosmopolitan attitudes, in addition to scarcity of cultural activity options in the local environment. The barriers to minimizing international travel included lack of knowledge on the climate change impact of flights, not feeling responsible for mitigation, and the dominant social norms that dictate that travel abroad is necessary for well-being.

Útdráttur

Neysla þéttbýlisbúa stuðlar að sívaxandi hluta losunar gróðurhúsalofttegunda og notkun auðlinda. Þar sem borgarform hefur áhrif á hegðun er leitin að sjálfbærustu gerð borgarforms áhugavert rannsóknarefni. Þétt byggð er almennt talin umhverfisvænust vegna minni losunar frá ferðum og minni orkunotkun íbúða. Rannsóknir hafa þó sýnt að tengingin er mun flóknari. Þó að umhverfisviðhorf hafi áhrif á umhverfishegðun flækir tilvist viðhorfs-hegðunar bilsins tengslin. Þessi ritgerð kannar landlæg einkenni, drifkrafta og hindranir umhverfisvænrar hegðunar, með sérstakri áherslu á flugsamgöngur. Hún notar blandaðar aðferðir til að kafa dýpra í hvata, réttlætingar og áður óþekkta drifkrafta. Í miðbæjum var mikil losun frá alþjóðaflugi og lítil frá ferðum innan borgarinnar, og þó að umhverfisviðhorf hafi haft áhrif á umhverfishegðun sem tengist matvælum, fatnaði og orkunotkun höfðu þau ekki áhrif á losun frá ferðalögum. Til viðbótar við staðsetningu heimilis voru drifkraftar losunar frá ferðum innan borgarinnar meðal annars viðhorf til bíla og löngun til að búa í úthverfi, en erilsamt borgarlíf og skortur á grænum svæðum dreif ferðalög innanlands. Einn helsti drifkraftur að baki ferðalaga erlendis var heimsborgaralegt viðhorf auk skorts á menningartengdum valkostum til tómstunda í nærumhverfinu. Hindranirnar til að lágmarka flug voru meðal annars skortur á þekkingu á loftslagsáhrifum flugs, að finna ekki til ábyrgðar fyrir að draga úr losun og ríkjandi félagsleg viðmið sem segja til um að ferðalög til útlanda séu nauðsynleg fyrir vellíðan.

Dedication

This thesis is dedicated to my mother, Lilja Gissurardóttir

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Article 1 (A1)

Árnadóttir, Á.; Czepkiewicz, M.; Heinonen, J. The Geographical Distribution and Correlates of Pro-Environmental Attitudes and Behaviors in an Urban Region. *Energies* 2019, 12, 1540, doi:10.3390/en12081540.

Article 2 (A2)

Czepkiewicz, M.; **Árnadóttir, Á.**; Heinonen, J. Flights Dominate Travel Emissions of Young Urbanites. *Sustainability* 2019, 11, 6340, doi:10.3390/su11226340

Article 3 (A3)

Heinonen, J.; Czepkiewicz, M.; **Árnadóttir, Á.**; Ottelin, J. Drivers of Car Ownership in a Car-Oriented City: A Mixed-Method Study. *Sustainability* 2021, 13(2), 619, doi:10.3390/su13020619

Article 4 (A4)

Árnadóttir, Á.; Czepkiewicz, M.; Heinonen, J. Climate change concern and the desire to travel: How do I justify my flights? *Travel Behaviour and Society* 2021, 24, 282–290, doi:10.1016/j.tbs.2021.05.002

Article 5 (A5)

Raudsepp, J.; **Árnadóttir, Á.**; Czepkiewicz, M.; Heinonen, J. Long-distance Travel and the Urban Environment: Results from a Qualitative Study in Reykjavík. *Urban Planning* 2021, 6(2), 257–270, doi:10.17645/up.v6i2.3989

Author Contributions

A1: The Geographical Distribution and Correlates of Pro-Environmental Attitudes and Behaviors in an Urban Region

Conceptualization, **Á.Á**., M.C. and J.H.; Data curation, M.C. and J.H.; Formal analysis, **Á.Á**., M.C.; Funding acquisition, M.C. and J.H.; Methodology, M.C.; Project administration, M.C. and J.H.; Supervision, M.C. and J.H.; Visualization, **Á.Á**., M.C. and J.H.; Writing—original draft, **Á.Á**.; Writing—review and editing, **Á.Á**., M.C. and J.H.

A2: Flights Dominate Travel Emissions of Young Urbanites

Conceptualization, M.C. **Á.Á.** and J.H.; Methodology, M.C., **Á.Á.**; Formal analysis, M.C. and **Á.Á.**; Data curation, M.C. and J.H.; Writing—original draft preparation, M.C.; Writing—review and editing, M.C., J.H. and **Á.Á.**; Visualization, M.C. and J.H.; Supervision, M.C. and J.H.; Project administration, J.H.; Funding acquisition, M.C. and J.H.

A3: Drivers of Car Ownership in a Car-Oriented City: A Mixed-Method Study

Conceptualization, J.H. and M.C.; Methodology, J.H., **Á.Á.** and M.C.; Validation, M.C., **Á.Á**. and J.O.; Formal analysis, J.H., M.C. and **Á.Á**.; Writing—original draft preparation, J.H., M.C. and **Á.Á**.; Writing—revisions, J.H., M.C., **Á.Á**., J.O.

A4: Climate change concern and the desire to travel: How do I justify my flights?

Conceptualization, **Á.Á.**, M.C. and J.H.; Data curation, **Á.Á.**; Formal analysis, **Á.Á.**, M.C. and J.H.; Funding acquisition, **Á.Á.**, M.C. and J.H.; Methodology, M.C. and J.H.; Project administration, J.H.; Supervision, M.C. and J.H.; Visualization, **Á.Á.**, M.C. and J.H.; Writing—original draft, **Á.Á.**; Writing—review and editing, **Á.Á.**, M.C. and J.H.

A5: Long-distance Travel and the Urban Environment: Results from a Qualitative Study in Reykjavík

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Abbreviations

ABC – attitude-behaviour-choice

ABG – attitude-behaviour gap

Ax – Article x

CCA – climate change awareness

GHG – greenhouse gas

GIS – geographic information system

LCA – life cycle assessment

PEA – pro-environmental attitude

PEB – pro-environmental behaviour

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1 Introduction

Almost all of our consumption behaviours contribute to some extent to climate change. Consumption drives production, which in turn produces greenhouse gas (GHG) emissions, wherever in the world the consumables are produced. Climate change is a global issue, and emissions travel beyond country boundaries and often linger in the atmosphere for several hundred years. Therefore, the quantity of global emissions left for not exceeding certain warming levels can be estimated for the whole world. In order to keep warming below 1.5°, carbon budgets have been suggested (Le Quéré et al., 2018; Millar et al., 2017), which if divided equally among the global population, put the per capita fair share of the remaining emission budget at around 5 tCO_2eq annually. This per capita emission budget decreases every year, and – if the assumed rate of reductions according to the mitigation curve is adhered to – it is estimated to stand at around 1 tCO_2eq a year in 2050 (Akenji, Lettenmeier, Koide, Toivio, & Amellina, 2019). Demand-side mitigation measures such as behavioural change are crucial (Myles et al., 2018), along with more understanding of the efficacy and drivers of pro-environmental behaviours (PEBs), and the barriers for behavioural change, if we are to have a chance at successfully keeping our lifestyles below the budgets. Lifestyles however are situated; consumption differs based on culture, norms, the availability of consumer goods, dwelling conditions, and other structures that shape everyday life, such as spatio-temporal organization of life around work, study, and commuting. Although around half of the world's population resides in urban areas, they are responsible for over 70% of global energy-related emissions (CCFLA, 2014).

This compilation therefore explores the drivers of environmentally significant behaviours and barriers to change in an urban context in a spatially sensitive way. Environmentally significant behaviours are defined in this thesis as behaviours that impact the environment negatively, while PEBs refer to minimizing that impact. The following subsections introduce the state of the art on the connection between urban form and environmentally significant behaviours, followed by how pro-environmental attitudes (PEAs) affect PEBs. It then presents the research problem and research questions, and finally introduces the thesis entity.

1.1 How Does Urban Form Affect Environmentally Significant Behaviours?

1.1.1 Urbanization

The process of urbanization has been found to increase greenhouse gas emissions on a macro scale. Studies on the relationship between urbanization and CO_2 emissions have found that an increase in urbanization, that is the percentage of a country's residents living in urban regions, leads to an increase in emissions, with the exception of higher-income nations with a strong environmental policy (Ponce de Leon Barido & Marshall, 2014). However, their data was based on national emission reporting and therefore did not take

life cycle emissions or consumption-based carbon footprints into account. Another study using the IPAT model, based on population, gross domestic product (GDP), and the share of industry and service sectors in GDP, found that while urbanization led to an increase in emissions across all income groups, it resulted in decreased energy use in the lowest income group (Poumanyvong & Kaneko, 2010). A recent review found that most studies conducted on consumption-based carbon footprints, including the global production and delivery chain emissions, found that residents of more urbanized areas generally have higher footprints despite the country's level of development (Ottelin et al., 2019). As cities often outsource their emissions, their territorial-based reporting can lead to a low-carbon illusion (Heinonen & Jóhannesson, 2019). The carbon footprints of urbanites have been found to be around 50% (Chen, Wiedmann, Hadjikakou, & Rowley, 2016) or 70% (Clarke, Heinonen, & Ottelin, 2017) from overseas. Emissions can be referred to as either direct (scopes 1 and 2 of the Greenhouse Gas Protocol (WBCSD/WRI, 2007)), such as personal vehicle fuel and housing energy, or indirect (scope 3), which constitute emissions from categories such as food and goods, both tangible and intangible (Ala-Mantila, Heinonen, & Junnila, 2014). Indirect emissions from the global supply chain are a significant contributor to the carbon footprints of urbanites (Athanassiadis et al., 2018; Clarke et al., 2017), and may become especially prominent as the carbon intensity of housing energy and transport declines with the adoption of electric vehicles, renewable energy sources, and the ever-increasing energy efficiency of buildings and household appliances. Overall, the emission profiles of urbanites tend to be dominated by indirect emissions, while the consumption-based carbon footprints of rural residents are more direct (Ottelin et al., 2019).

1.1.2 Urban Form

The urban form within a city can affect the carbon footprints of its residents. The dominant idea is that the compact city is the most environmentally sustainable urban form, as studies have shown that dense living leads to lower emissions from household energy consumption, construction, and daily transportation (Anderson, Wulfhorst, & Lang, 2015; Glaeser & Kahn, 2010; Norman, MacLean, & Kennedy, 2006; Wiedenhofer, Smetschka, Akenji, Jalas, & Haberl, 2018). However, several studies which take a more comprehensive approach to the carbon accounting of residents have found that the consumption-based footprints of central dwellers are either bigger (Heinonen, Jalas, Juntunen, Ala-Mantila, & Junnila, 2013a; Heinonen & Junnila, 2011a) or similar (Chen, Hadjikakou, Wiedmann, & Shi, 2018; Muñiz & Rojas, 2019) to those of rural or suburban residents, although some studies have found the footprint to be higher in affluent urban outskirts than in urban cores (Heinonen & Junnila, 2011c; Jones & Kammen, 2014). The following subsections discuss some of the contradictions of the compact city being the most environmentally sustainable urban form, covering aspects of affluence, energy consumption, sharing, compensation, the rebound effect, and agglomeration benefits.

Affluence

As affluence drives consumption, it is not surprising that comparing footprints between neighbourhoods or between urban and rural areas, with spatial sorting of income and status, would yield results of differing carbon footprints. Therefore, controlling for income is essential when studying how urban form affects emissions. However, controlling for income does not necessarily show the most accurate depiction of the comparative consumption-based carbon footprints of residents in rural and urban areas, as urbanization itself can lead to a rise in affluence (Ala-Mantila et al., 2014). In addition, attitudes and

cultures vary in space, which adds another layer of complexity to assessments. In any case, the patterns are well established in locations where residents are generally highly mobile and relatively affluent. Even when limiting measurements to only emissions from mobility or housing, efficiency gains resulting from density have been found to be nulled out just by the inclusion of emissions from long-distance travel (Reichert, Holz-Rau, & Scheiner, 2016) and second homes (Muñiz & Rojas, 2019). Despite this, urban planning policies continue to plan for densification while at the same time accommodating for economic growth (Næss, Saglie, & Richardson, 2020), and as increased affluence leads to higher consumption-based carbon footprints, it undoubtedly counteracts any emission gains resulting from shorter travel distances within cities.

Energy Consumption

It is undeniable that behaviour differs depending on how the built environment is arranged. As put by Næss (2015, p. 282): *"Buildings and physical infrastructure normally do not actively trigger things to happen, but they can in principle (usually in interplay with other causal powers) enable, augment, facilitate, constrain, stifle or prevent the occurrence of events and situations in such a way that the result differs from what would otherwise have been the case."* This can for example be seen in the case of household energy consumption. It has been found that the behaviour of residents living in apartment buildings connected to district heating often has little impact on household energy use, as only a small share is directly controllable by residents (Kyrö, Heinonen, Säynäjoki, & Junnila, 2011). In addition, they have little monetary incentive for reduction (Heinonen & Junnila, 2014), as the bills are often paid as a percentage based on floor area. On the other hand, residents living in detached houses in rural areas have a direct monetary incentive to save energy. A study in Finland showed that people living in rural areas had a much higher share of renewable energy use than those living in urban apartment buildings (Heinonen & Junnila, 2014), as they have more control over switching to an alternative energy source. This behavioural difference led to significantly lower energy consumption per square meter than in urban areas, despite the efficiency gains in apartment buildings, where each apartment has fewer outer walls. However, as rural residents often have larger living spaces, the per capita energy consumption was similar (Heinonen & Junnila, 2014). The urban form factors can therefore greatly influence emissions from household consumption of energy, regardless of the behavioural intent of individuals.

Sharing

Urban form is also associated with household size, as the further away from the urban core a household is, the larger it is on average (Ala-Mantila, Ottelin, Heinonen, & Junnila, 2016), and rural households have been found to be about double the size of those in the city centre (Fremstad, Underwood, & Zahran, 2018). As larger households share more resources, their per capita carbon footprints tend to be lower (Ala-Mantila et al., 2016; Fremstad et al., 2018; Gill & Moeller, 2018; Ivanova & Büchs, 2020; Underwood & Fremstad, 2018), and small centrally located households have been found to partake more in *parallel consumption* (Heinonen et al., 2013a; Heinonen, Jalas, Juntunen, Ala-Mantila, & Junnila, 2013b). The concept of *parallel consumption* was coined in 2013 with the publication of the papers *Situated Lifestyles* I and II (Heinonen et al., 2013a, 2013b), and explains how urbanites multiply their consumption by possessing space and appliances within their homes, while also utilizing multiple services and spaces outside of it much more frequently than those living in rural areas with much reduced access to these services.

A simple example would be owning a television, an oven, and a coffee maker, while still frequently going to the cinema, restaurants, and cafés. Although larger households can benefit from household economies of scale resulting in smaller footprints due to sharing of resources, this is not true for transportation emissions (Ala-Mantila et al., 2016; Ivanova & Büchs, 2020).

Compensation

A recent review found that urbanites generally travel more internationally than their suburban counterparts (Czepkiewicz, Heinonen, & Ottelin, 2018). There are several concepts which attempt to explain the high footprints of residents living in a dense urban environment. One of them is the *compensation hypothesis*, which proposes that residents compensate for deficiencies or escape annoyances in the local environment by engaging in leisure travel away from the city they live in (Czepkiewicz, Klaas, & Heinonen, 2020). It has been studied quantitatively on a broad scale based on population density, where emissions saved in daily activities seem to be emitted during weekends and holidays in dense environments (Muñiz & Rojas, 2019), although the causal character of this activity pattern is unclear, and this might instead be a manifestation of the *rebound effect*, discussed below. The compensation hypothesis has however also been examined based on local environmental factors such as lack of green areas and private gardens, and a high-density urban environment, which have been found to be compensated for with second homes outside of the city (Strandell & Hall, 2015). This field of study is relatively understudied and while causal links have yet to be verified, a recent study found a weak indication that when the residential location lacks greenness, but individuals prefer their local environment to be green, they compensate for that deficiency with domestic trips (Czepkiewicz, Klaas, et al., 2020). It is however important to note that domestic travel was not the type of long-distance trip that was responsible for geographical trends in travel emissions, but the trends of high emissions in central areas were mostly due to international travel emissions via flights, which in addition generated much higher GHG emissions. That same study concludes that attitudes and preferences, such as *cosmopolitan attitudes*, preference for nature in urban environments, and preferred leisure trip type, play a key role in how or if residents compensate with long-distance travel. In addition, *cosmopolitan attitudes*, attitudes that favour experiencing new places and varied cultures, agglomerate in dense and well-connected cities (Czepkiewicz, Klaas, et al., 2020).

Rebound Effect

Another concept related to the high footprints of urban dwellers is the *rebound effect*, where the general assumption is that "*money saved in one area will be spent elsewhere*" (M. Lenzen & Dey, 2002, p. 383). Direct rebound effects are when higher efficiency leads to more consumption of that same energy service, a concept first coined by Alcott (2005) as the "Jevons' paradox", named after William Stanley Jevons' 1865 piece on how the technological efficiency gains of a new coal-fired steam engine resulted in more consumption of coal (Alcott, 2005). The direct rebound effect referred to here manifests itself in the way that, as that improved energy service becomes less expensive along with lower energy input needs, simply more is used. Rebound effects can be measured not only in energy use, but also in emissions. Indirect rebound effects are when either energy or emissions saved in one category, such as with more efficient household appliances or personal vehicles, are then spent in other categories due to monetary savings from higher efficiency. These "other categories" also require energy or emit GHGs, so the initial saving

rebounds. Encouragement of behaviours leading to this indirect rebound effect is even visible in advertising campaigns, as illustrated by Chitnis, Sorrell, Druckman, Firth, & Jackson (2013) in their Figure 1, which shows a Tesco advertisement with the phrase "Turn lights into flights," and Figure 1 below, a photo of a billboard advertising an electric vehicle photographed by Harpa Stefánsdóttir in Reykjavík, which puts forth the question "Petrol or a holiday abroad?".

Figure 1: "Bensín eða utanlandsferð? (e. Petrol or a holiday abroad?)" Photographed by Harpa Stefánsdóttir.

When planning a city it is important to be aware of these effects, as they can undermine the efficacy of mitigation strategies. Urban planning typically deploys densification strategies to decrease car-dependency and the associated GHG emissions, but a decrease in personal vehicle travel has been found to have the rebound effect of more international flights (Heinonen et al., 2013a; Ottelin, Heinonen, & Junnila, 2017). However, findings are not unanimous. One study found no evidence of a rebound effect of increased flights due to decreased driving (Mattioli, Morton, & Scheiner, 2021), and another found that even though density had a rebound effect reflected in increased expenditure on for example flights and restaurant meals, the effects were relatively small (Underwood & Fremstad, 2018). It is a complex task, as there needs to be a balance between monetary incentives for residents to engage in environmentally significant behaviours, such as with subsidies for public transport and electric vehicles, while keeping the prices high enough to avoid rebound effects, or alternatively, encouraging monetary spending on less GHG intensive activities.

Agglomeration Benefits

Another concept explaining the carbon footprints of urban dwellers is agglomeration economies (Ciccone & Hall, 1996), where higher purchasing power leads to more consumption in general; higher profits for companies showing in yet higher wages and ever-increasing consumption. The density of the urban environment creates conditions for an increase in economic activity which in turn presents opportunities for wealth (Heinonen

et al., 2013a; Xu, Chang, & Wang, 2019), and a higher income has been associated with an increase in carbon footprints (Gill & Moeller, 2018; Heinonen et al., 2013b; Heinonen & Junnila, 2011a; Muñiz & Rojas, 2019; Wiedenhofer et al., 2018). In addition to creating more wealth, agglomeration economies create more favourable conditions for consumption of goods, culture, and services (Gill & Moeller, 2018; Poom & Ahas, 2016). Services constitute an ever-increasing proportion of the carbon footprint of consumers (Heinonen & Junnila, 2011b). Accessibility to services can affect consumption of them (Wiedenhofer et al., 2018; Xu et al., 2019), but this can also have environmental benefits; density can result in more options to behave in a sustainable manner, with increased accessibility for example of organic food (Lo, 2016). Regarding the will to then act in a more sustainable manner, it has been found that residents in urban areas have higher PEAs than those in rural ones (Yu, 2014), although the level of environmental concern can differ depending on category; while urbanites may be more concerned about pollution, rural residents have been found to be more concerned about conservation. In addition, the same study found that rural residents were more likely to behave depending on their environmental attitudes (Berenguer, Corraliza, & Martín, et al., 2005).

1.2 How Do PEAs Affect PEBs?

1.2.1 Attitude-Behaviour Gap

The attitude-behaviour gap (ABG), sometimes referred to as the value-action gap, is when attitudes towards sustainable consumption deviate from actual behaviour (Terlau & Hirsch, 2015). There is no single framework that has successfully captured all factors that influence the magnitude of the ABG. The factors are multiple and can either be external, such as cultural and economic, or internal, where values, beliefs, norms, awareness, and knowledge are considered separately (Kollmuss & Agyeman, 2010).

Different frameworks have been used to explore the gap with varying results. Many have found the connection of environmental awareness or attitude to various PEBs weak or completely missing (Bronfman, Cisternas, López-Vázquez, Maza, & Oyanedel, 2015; Moser, 2015; Newton & Meyer, 2013; Poortinga, Steg, & Vlek, 2016; Tabi, 2013; Whitmarsh, 2009; Whitmarsh & O'Neill, 2010), but results also differ depending on which PEB and which attitudinal factors are studied. For example, attitudes are only weakly translated into PEBs related to clothing purchases, while various values are key predictors (Jacobs, Petersen, Hörisch, & Battenfeld, 2018). In some cases, PEAs could predict PEBs related to categories such as diet, energy use, and local travel (Bruderer Enzler & Diekmann, 2015, 2019; Díaz-Siefer, Neaman, Salgado, Celis-Diez, & Otto, 2015).

Although the more environmentally conscious have been found to be less likely to travel by air (Bruderer Enzler, 2017), most studies have found that air travel has an especially large ABG. People are more willing to change their day-to-day lifestyles to fit with their pro-environmental beliefs rather than flight behaviour (Alcock et al., 2017; S. Barr, Shaw, Coles, & Prillwitz, 2010; Davison, Littleford, & Ryley, 2014; Reis & Higham, 2016). This is quite concerning, as flights can contribute to a significant share of a highly mobile individual's carbon footprint. Flights constitute roughly 2.5% of global emissions (Graver, Zhang, & Rutherford, 2019) and tourism around 8% (Manfred Lenzen et al., 2018), which are even more alarming numbers considering the estimation that only around 2-4% of the

world's population participate in international travel (Gössling & Humpe, 2020; Gössling & Peeters, 2007). Studying the relationships between one of the most environmentally significant behaviours, holiday travel, and general attitudes is complex, and the behaviour has been connected to factors such as identity (Hibbert, Dickinson, Gössling, & Curtin, 2013; McDonald, Oates, Thyne, Timmis, & Carlile, 2015), values (Büchs, 2017), and norms (Jacobson, Åkerman, Giusti, & Bhowmik, 2020; Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007; Söderberg & Wormbs, 2019). In the context of air travel, the ABG has been called the "Flyers' dilemma" (Higham, Cohen, & Cavaliere, 2014; McDonald et al., 2015; Young, Higham, & Reis, 2014) and research has focused on the cognitive dissonance experienced in this situation (Becken, 2007; Randles & Mander, 2009), which is a feeling of discomfort when an individual's attitudes do not match with their behaviours.

1.2.2 Justifications and Barriers to Reducing Flights

Minimizing air travel bears tremendous mitigation potential, but behavioural change in this domain can be seen as arduous. The most mobile tourists have been found to be the least willing to reduce their air travel, but are instead more willing to pay carbon taxes or offset their emissions (Barr et al., 2010; McKercher, Prideaux, Cheung, & Law, 2010), and these mobile individuals are in turn likely to be well educated on environmental issues (Young et al., 2014). Although there still exists a knowledge gap among the public, where they do not have adequate knowledge on the specific impacts flights have on climate change (Becken, 2007; Cocolas, Walters, Ruhanen, & Higham, 2020; Randles & Mander, 2009; Reis & Higham, 2016), even the highly climate aware are more likely to change the way they think about the environmental impact of flying than to change the behaviour itself (McDonald et al., 2015). For this, they use a scheme of justifications to reduce the uncomfortable feelings of cognitive dissonance, such as compensatory green behaviour (McDonald et al., 2015). This green behaviour practiced around the home can be used as an excuse to travel abroad (Barr et al., 2010; Dickinson, Robbins, & Lumsdon, 2010; Hares, Dickinson, & Wilkes, 2010), and consumers have been found to think about an average impact of their behaviours rather than the sum of them, which gives a low-carbon lifestyle illusion (Sorqvist & Langeborg, 2019). Other justifications are that holiday travel is an exception (Juvan & Dolnicar, 2014), or that there are not enough viable alternative options (Jacobson et al., 2020; Whitmarsh & O'Neill, 2010). One of the main justification strategies of air travel is to place responsibility onto government organizations (Becken, 2007; Jacobson et al., 2020; Juvan & Dolnicar, 2014; Lorenzoni et al., 2007; Reis & Higham, 2016), but this may be most true for individuals who have little air travel-specific climate change knowledge (Dickinson et al., 2010). However, it also may result from general views on how responsibility should be distributed in complex issues such as climate change. People feel that their personal actions are of little importance (Higham et al., 2014; Jacobson et al., 2020; Juvan & Dolnicar, 2014; Lorenzoni et al., 2007), or that technology will solve the climate crisis (Lorenzoni et al., 2007).

In any case, the predominant thinking is that flying is important for wellbeing and social status (Dolnicar, Lazarevski, & Yanamandram, 2013; Richards, 1999), and bears tremendous value of freedom (Becken, 2007). Norms can be a difficult barrier to overcome, and seem to be a stronger factor than PEAs; even individuals who want to quit flying find themselves "trapped" in them, as well as in other social practices and structural factors (Jacobson et al., 2020).

Some environmentally conscious individuals have however reduced their travels by plane, and it has been found that those individuals have managed to distance themselves from the dominant social norms; they take action regardless of what they think the climate benefits are, but they also accept that their behaviour does have an impact (Büchs, 2017). This can be further extended to personal responsibility for individual actions, and feeling a responsibility towards future generations and populations in distant places (Wormbs & Söderberg, 2021). Those who have quit flying have realized the urgency of climate change (Söderberg & Wormbs, 2019; Wormbs & Söderberg, 2021) and have most often internalized climate change knowledge and have deeper negative feelings such as anxiety, frustration and guilt. Good past experience with alternative infrastructure such as trains is also a crucial factor in the decision to quit (Jacobson et al., 2020). The social context has been found to have an effect on the decision to quit flying, where especially children are noted as inspiring greater morality (Wormbs & Söderberg, 2021).

1.3 Research Problem and Research Question

To keep the emissions from our lifestyles below the per capita budgets left for 1.5° warming, behavioural change is essential (Myles et al., 2018). The role of urban form in influencing behaviours is still largely unknown, as results tend to be contextual. Exploring how behaviours differ in space, and what the other drivers of those behaviours are, could help distinguish between direct and indirect influences of the built environment. In addition, although studies have attempted to shed light on which attitudinal aspects are needed to bridge the ABG in aviation, exploration of whether those aspects still hold true in different geographical contexts is still needed, along with a greater understanding of how the barriers differ depending on individual attitudes. Such repetition of studies with multiple distinct cases is imperative for theory building, as if similar findings still hold in different cultures and geographical contexts, the robustness of the findings increases.

The research questions of this thesis are:

1. What are the spatial characteristics of PEBs related to produce, clothing, and household energy use, and of the environmentally significant behaviours related to local, domestic, and international travel?
2. What are the drivers of the environmentally significant behaviours related to local, domestic, and international travel?
3. What are the barriers to changing environmentally significant behaviours related to local and international travel?

Section 1.4 describes the scope and boundaries within which the research questions are studied. It narrows down the research questions to the case studies and introduces the thesis entity.

1.4 The Thesis Entity

This thesis consists of five peer-reviewed articles, listed on page xv, along with this compilation. It focuses on how behaviours in the realm of local, domestic, and international travel emissions cluster in space and how urban form characteristics predict

them (A1, A2), but it also examines spatial characteristics of PEBs related to clothing, produce and household energy (A1). It dives deeper into the influencing factors of local (A3), domestic (A5), and international travel (A4, A5), and how those factors connect to the urban environment, either directly or through more complex causal mechanisms. Finally, it explores the barriers to acting more sustainably when it comes to travel, and how they differ depending on cultural, attitudinal, and geographical context (A4).

The first article published, *The Geographical Distribution and Correlates of Pro-Environmental Attitudes and Behaviors in an Urban Region* (A1), explored how urban zones and PEAs were associated with PEBs related to clothing, produce, household energy, and travel emissions in Helsinki Metropolitan Area, henceforth referred to as Helsinki. Results related to travel emissions were the most interesting, prompting an investigation into the predictors, structure, distribution, and levels of local, domestic, and international emissions in another area; Reykjavík Capital Region, hereafter referred to as Reykjavík. The second article titled *Flights Dominate Travel Emissions of Young Urbanites* (A2) found similar spatial and attitudinal patterns; PEA and climate change awareness (CCA) did not affect the emissions. In addition, local emissions were the lowest near the city center and high international travel emissions clustered in the central part of Reykjavík, while various other preferences and attitudes predicted emissions. These findings motivated a deeper analysis of the drivers of emissions. The third article, *Drivers of Car Ownership in a Car-Oriented City: A Mixed-Method Study* (A3), studied how strong the impact of urban form is on car ownership, compared to attitudes and socio-demographic characteristics, and strove to find an explanation for the high rate of car ownership in Reykjavík. A2 had quantified annual travel emissions, showing that on average the emissions from international travel were around three times higher than from local travel, and the sample had high PEAs and CCA which actually predicted slightly higher international emissions. This inspired an exploration of how the climate aware residents of Reykjavík justify their air travel, whether these justifications differed depending on level of awareness, and if there was any indication of willingness to reduce flying due to CCA. This was the scope of the fourth article *Climate change concern and the desire to travel: How do I justify my flights?* (A4), and – because of the high mitigation potential of behavioural change in this domain – it became a focal point of discussion in this compilation. The fifth article, *Long-distance Travel and the Urban Environment: Results from a Qualitative Study in Reykjavík* (A5), then set out to examine the patterns and motivations for long-distance travel, and whether or not they were connected to urban form.

In the next sections, this thesis first introduces the methodological context, which includes the choice of a mixed-method orientation, the methods used and the relevant variables. It is then followed by the results of the five articles, presented both individually and as a whole. The discussion then includes the contribution of the thesis and positions it among previous literature, discusses the validity and reliability of the study, and finally presents potential future research directions.

2 Methods and Data

This section introduces the methodological context of the study, starting from the selection of the case study approach and the general mixed-method orientation of the thesis. It then presents the materials and methods used for each article, and finally the composition of the variables used in the analysis is presented.

2.1 Methodological Context

2.1.1 Case Studies

This thesis is a multiple case study, which is useful for forming context-dependent knowledge (Flyvbjerg, 2016). It analyses two cases of urbanites, aimed to be representative of a specific age group in Helsinki and Reykjavík. Those cases were of interest because of their high affluence (with the resulting high carbon footprints), their expected high level of PEAs and climate change concern (based on them being ranked the top two countries on the Environmental Performance Index at the time of initial data collection (Hsu, Esty, Levy, & de Sherbinin, 2016)), as well as the unique geographical conditions of Iceland. This method was especially suitable in a field where the specific cultural and geographical differences in the cases can show whether or not it is the urban form itself which affects behaviours, and whether the same factors related to environmental knowledge and concern are sufficient to inspire behavioural change. Multiple case studies can form theories when knowledge accumulates through similar findings (Eisenhardt & Graebner, 2007).

2.1.2 Mixed-Method Orientation

Although several studies have assessed and compared the carbon footprints of residents living in urban, suburban, and rural areas, as well as the ABG, less is known on the drivers of travel emissions and the extensive gap regarding international flight emissions. For both these subjects, the type of results required to fully understand the causal mechanisms calls for an in-depth qualitative analysis.

Qualitative materials can be used to explain the underlying mechanisms behind quantitative correlations (Næss, 2018), and they are especially effective when used together with those quantitative materials (Szajnfarber & Gralla, 2017). By themselves, the quantitative methods can fail to capture a sufficient amount of detail, which calls for the use of mixed-method approaches where quantitative results provide indications of a trend while explanatory qualitative methods can explore the causality of that trend (Ivankova, Creswell, & Stick, 2016; Næss, 2018).

This research utilizes mixed-methods. Instead of using triangulation, where the same phenomenon is researched by two different methods, this thesis uses nested analysis; a specific mixed-method approach which "*combines the statistical analysis of a large sample of cases with the in-depth investigation of one or more of the cases contained*

within the large sample." (Lieberman, 2005, p. 436). While the methods complement each other, they also provide guidance for future analysis. Statistical, spatial, and descriptive analysis explored both survey data sets, and the exploration provided insights for forming the interview protocol, utilized for qualitative data collection.

In A1 and A2, the quantitative analysis revealed that PEA did not affect travel emissions, so the qualitative analysis aimed at diving deeper into *why*. Spatial autocorrelation of international travel emissions was found within both datasets, but regression models on both domestic and international travel revealed little explanatory power of residential location. They did however point towards potential explanations, such as cosmopolitan attitudes, so qualitative analysis was crucial to identify which urban form aspects affect long-distance travel, if any, and to reveal potential connections which were not visible in the quantitative data. These connections could either have been confounded by other variables, or could simply be previously unidentified and therefore not accounted for in the models.

In addition, qualitative analysis in A3, A4, and A5 identified additional variables to include in future statistical analysis to increase the model's explanatory power, for local, domestic, and international travel emissions, respectively.

2.2 Overview of Each Article's Methods and Data

The articles that form this thesis entity utilized a wide scope of methods within the mixed-method context. For quantitative analysis, regression and spatial statistics were used on data collected with a softGIS survey, which combines survey questions with an online map (Kahila & Kyttä, 2009). For qualitative analysis, a two-step interpretation method was used on a dataset of semi-structured interviews. The methods are described below in more detail, and the ones used in each article are summarized in Table 1.

Table 1: Data and methods used in each article

Article	Title	Data and methods
A1	The Geographical Distribution and Correlates of Pro-Environmental Attitudes and Behaviors in an Urban Region	Multiple linear regression, binary logistic regression and spatial statistical analysis on a dataset collected with a softGIS survey. Random sample of 841 participants from Helsinki.
A2	Flights Dominate Travel Emissions of Young Urbanites	Multiple linear regression, binary logistic regression and spatial statistical analysis on a dataset collected with a softGIS survey. Random sample of 706 participants from Reykjavík.
A3	Drivers of Car Ownership in a Car-Oriented City: A Mixed-Method Study	Mixed-methods. Hierarchical regression on a dataset collected with a softGIS survey. Random sample of 686 participants from Reykjavík. Two-step interpretation method on a dataset of 21 semi-structured interviews.
A4	Climate Change Concern and the Desire To Travel: How Do I Justify My Flights?	Two-step interpretation method on a dataset of 21 semi-structured interviews with residents of Reykjavík.
A5	Long-distance Travel and the Urban Environment: Results from a Qualitative Study in Reykjavík	Two-step interpretation method on a dataset of 21 semi-structured interviews with residents of Reykjavík.

2.3 Data Collection

The data used in the articles of this compilation consists of three datasets; two quantitative (A1, A2, A3) and one qualitative (A3, A4, A5).

The quantitative datasets were both collected using a softGIS method (Kahila & Kyttä, 2009), which combines survey questions with an interactive map on which respondents can mark down locations. They were targeted to individuals from the age of 25 – 40 in two Nordic capitals, Helsinki in Finland (A1) and Reykjavík in Iceland (A2, A3). The narrow age group was chosen to lessen the effect of life course variables such as independence from parents and employment, and generational differences such as growing up with good access to information and communication technologies.

For the Helsinki data collection (A1), the survey was sent via a personal letter to a random sample of 5000 individuals, and the response rate was 16.82% (841 responses). For Reykjavík (A2), personal invitation letters were sent to a random sample of 6000 individuals, and after deducting incomplete responses and returned letters the response rate was 13.6% (706 responses). For both Helsinki and Reykjavík, the letters were sent in two rounds as explained in more detail in A1 and A2.

Qualitative data collection (A3, A4, A5) was performed in Reykjavík by purposefully selecting a diverse group from the Reykjavík survey sample. The aim was to have representatives from all socio-demographic groups of interest, as well as individuals with different modality styles, and those with high climate change concern and high emissions from international travel. This was possible as some respondents had expressed willingness to participate in further research and had entered their emails into the Reykjavík survey. Three rounds of invitations were sent via email, which resulted in a total of 21 interviews, which were 45 – 90 minutes long. The interviewees' gender, age, residential location, and household type are presented in Table 2. The interviews were semi-structured and followed an interview protocol developed from previous literature and results from A1 and A2. Six pilot interviews were taken to further develop the protocol before utilizing it with the selected respondents. The recordings of the interviews were transcribed and those taken in Icelandic were translated to English.

Table 2: Age, gender, residential location, and household type of interviewees

ID	Gender	Age	Urban zone	Household type
1	Male	40	Basic public transportation	Family w. children
2	Female	40	Fringe of central pedestrian	Single
3	Male	29	Intensive public transportation	Single
4	Male	29	Fringe of central pedestrian	Family w. children
5	Female	29	Central pedestrian	Couple
6	Male	41	Car-oriented	Family w. children
7	Female	40	Car-oriented	Family w. children
8	Female	38	Central pedestrian	Family w. children
9	Female	26	Central pedestrian	Single
10	Female	37	Fringe of central pedestrian	Single
11	Female	30	Car-oriented	Family w. children
12	Male	36	Central pedestrian	Family w. children
13	Female	39	Car-oriented	Family w. children
14	Female	36	Fringe of central pedestrian	Family w. children
15	Female	36	Fringe of central pedestrian	Family w. children
16	Female	34	Car-oriented	Couple
17	Female	30	Basic public transportation	Couple
18	Female	36	Car-oriented	Couple
19	Female	42	Car-oriented	Family w. children
20	Female	27	Fringe of central pedestrian	Single
21	Female	42	Car oriented	Single

2.4 Regression and Spatial Statistics

For A1 and A2, the regression analyses were run in IBM SPSS Statistics 24. For the statistical analysis on each of the PEB variables (see section 2.4), Ordinary least squares regression (OLS) was used (A1). As there were many respondents who had not travelled at all in the surveyed year, there was a need to run two separate analyses for each of the travel emission categories (local, domestic, and international); an OLS regression on the amount

of emissions, and a binary logistic regression on participation in emissions (A1, A2). For A3, the glm.nb function of the MASS package in R was used to perform a hierarchical logistic regression on car ownership. The spatial analysis (A1, A2) was conducted in ArcGIS 10 using both Global Moran's I statistic (Esri, 2018b), to check if there was clustering in space, and Getis-Ord Gi* (Esri, 2018a) to identify the areas where high or low values cluster.

2.5 Interview Analysis

A two-step interpretation method was used to analyze the interview data, following an example from Næss (2018). This method was chosen to remain open and flexible for new insights to arise, as although some variables were identified as significant predictors, the explanatory power of the models was low which pointed to the existence of unidentified factors of influence. Local (A3) and long-distance (A4, A5) travel were interpreted separately. For local travel, a list of six themes and twenty-two questions under each theme was used for initial analysis, where each interview was interpreted separately. Each interpretation was then summarized by question, resulting in an overall holistic response summary for each question. The interpretations were validated by a second researcher, who was present at the interview. For long-distance travel, there were forty-four questions under fifteen themes. The interpretations from questions under different themes were utilized for each of the three articles in this compilation (A3, A4, A5), and many of the themes have not yet been utilized in published research. The questions utilized are presented in Tables 3-5, which cover the questions from A3, A4, and A5, respectively.

A3 studied the impact of urban form, attitudes, and socio-demographic characteristics on car ownership, aiming to explain the high car ownership rates in Reykjavík. The interview data was interpreted using the questions in Table 3 below.

Table 3: The themes residential location, car ownership and mode choice along with the questions utilized for interpretation analysis for A3

Themes	Research questions
Residential location	Is there indication that travel-related reasons or motivations affected the residential location choice?
Car ownership	How does the respondent reason possessing / not possessing a vehicle (or several)?
Car ownership	How does the respondent describe the rationales behind choosing or possessing a vehicle with specific qualities?
Car ownership	Is there indication of societal underlying reasons for vehicle possession or avoidance of vehicle possession?
Car ownership	Is there indication of other underlying reasons for vehicle possession or avoidance of vehicle possession?
Mode choice	What are the rationales behind choosing or not choosing the car?
Mode choice	What are the rationales behind choosing or not choosing to walk?
Mode choice	What are the rationales behind choosing or not choosing the bus?
Mode choice	What are the rationales behind choosing or not choosing to cycle?
Mode choice	Is there an indication of societal underlying reasons for mode choice of the respondent?
Mode choice	Is there an indication of societal underlying reasons for mode choice of others?

A4 set out to explore how residents of Reykjavík justify their air travel despite their high CCA, and how the justification strategies differed depending on level of awareness. Willingness to reduce flying was also studied. The questions used for interpretation are presented in Table 4 below.

Table 4: Interpretation theme environmental & climate change awareness and concern along with the questions utilized for interpretation analysis for A4

Themes	Research questions
Environmental & climate change awareness and concern	How does the respondent consider environmental impacts of travel?
Environmental & climate change awareness and concern	What environmental impacts related to travel does the respondent mention?
Environmental & climate change awareness and concern	Is there an indication of a willingness to change travel behaviour due to environmental reasons? If yes, how, and what would they change? If not, why?
Environmental & climate change awareness and concern	What does the respondent do in daily life to limit his or her impact on the environment?
Environmental & climate change awareness and concern	How does the respondent weigh the benefits of travel against the environmental impacts?
Environmental & climate change awareness and concern	How does the respondent rationalize travelling despite the environmental impact?
Environmental & climate change awareness and concern	What does the respondent mention as good ways to limit the environmental impact of travel?

In A5, the patterns and motivations for long-distance travel, both domestic and international, were studied along with their connection to urban form. Table 5 shows the many themes and questions utilized for the analysis.

Table 5: Interpretation themes household situation, consumption and lifestyle choices, summer house, dwelling characteristics, neighborhood characteristics, other daily life circumstances, well-being effects, other motivations and rationales, general interpretation, and emergent themes, along with the questions utilized for interpretation analysis for A5

Themes	Research questions
Household situation	What is the household structure and situation?
Consumption and lifestyle choices	Whether and how does owning a car connect to long-distance travel?
Consumption and lifestyle choices	How do major lifestyle choices influence long-distance travel patterns directly and indirectly?
Consumption and lifestyle choices	Is there a connection between daily travel patterns and preferences and long-distance travel choices?
Summer house	What is the influence of having a summer house on travelling domestically?
Summer house	What is the influence of having a summer house on travelling internationally?
Dwelling characteristics	Do they mention any dwelling characteristics or related stressors as affecting their travel abroad and domestically, or is there indication of it? If yes, which ones?
Dwelling characteristics	Is there indication that the place of residence would have been selected so that it leaves the resident enough money to travel?
Dwelling characteristics	Is there any indication of having a garden and spending time there being connected to long-distance travel?
Neighborhood characteristics	Do they mention the characteristics or stressors related to the city or neighbourhood affecting their travel abroad and domestically, or is there indication of it? If yes, which ones?
Other daily life circumstances	Is there indication about other daily life stressors affecting leisure travel choices and patterns?
Well-being effects	What are the expected and experienced well-being benefits from leisure travel abroad?
Well-being effects	What are the expected experienced well-being benefits from leisure travel within Iceland?
Well-being effects	How is weather mentioned in relation to long-distance travelling?
Well-being effects	What characteristics of travel destinations do the respondents value? How are these characteristics connected to well-being effects and reasons to travel?
Other motivations and rationales	What other motivations and rationales does the respondent mention behind long-distance travel?
General interpretation	A general interpretation and description of each person's travel practices and preferences (what is the person like as a traveller)

2.6 Variables

This section provides an overview of the variables used in analysis which are mentioned in this thesis, to fully understand what constituted them. The first subsection presents PEBs,

attitudes, and preferences, the second introduces the residential zones, and the third presents some information on the calculations behind travel emissions.

2.6.1 PEBs, Attitudes, and Preferences

Factor analysis was performed on groups of survey answers to reduce data and produce independent factors. The answers to survey statements presented in this section were given on a Likert scale with five answer options ranging from "strongly agree" to "strongly disagree", which were assigned a numerical digit from 1-5. In A1, the factor scores produced from the Helsinki data were used directly in regressions (Tables 5 and 6), while as the factor solutions explained little variance in A2, the analysis was based on sums of answers belonging to the factor. The rotated factor scores for A1 are presented in Tables 5 and 6, while the rotated factor loadings for A2 are presented in Tables 7 and 8.

The factor analysis of PEBs produced three independent factors: clothing, household energy, and produce (Table 6). The clothing factor consisted of answers to questions on buying second-hand, ethical, and environmental clothing. Household energy consisted of reducing heating in unoccupied rooms, keeping heating low and reducing hot water temperature. The produce factor consisted of buying organic and local produce, along with buying items with little packaging.

Table 6: Factor analysis of PEBs from A1, Helsinki

	Clothing	**Household energy**	**Produce**
Reduce heating in unoccupied rooms		.757	
Reduce hot water temperature		.542	
Switch off lights in unoccupied rooms			
Keep heating low to save energy		.740	
Use high efficiency appliance			
Buy organic produce			.585
Buy local produce			.707
Purchase items with as little packaging as possible			.494
Buy second-hand clothes	.534		
Choose to buy clothes according to environmental impact	.834		
Choose to buy clothes according to ethical aspects of production	.786		

For the PEA variable in A1, the factor analysis determined that only one factor was needed for all questions related to statements on environmental issues. The statements are presented in Table 7.

Table 7: Factor analysis of PEA from A1, Helsinki

	PEA
I want to live as ecologically as possible	.853
I am very concerned about environmental issues	.787
I think about how I can reduce environmental damage when I go on holiday	.760
I think about the environmental impact of services I use	.836
When shopping, I rarely think about the environmental impact of the things I buy [reversed]	.713

In A2, however, factor analysis was conducted on a wider range of attitudinal questions than in A1. This was partly due to PEA not affecting travel emissions in A1, so it set out to identify other attitudinal predictors. The resulting factors were: PEA, CCA, cosmopolitan attitude in travel, and preference for urban vs. natural settings in travel (Table 8).

Table 8: Factor analysis of PEA, CCA, cosmopolitan attitude in travel, and preference for urban vs. natural settings in travel from A2, Reykjavík

	PEA	**CCA**	**Cosmo-politan Attitude**	**Preference for Urban vs. Natural**
I want to live as ecologically as possible	.572			
I am very concerned about environmental issues	.538	.314		
I think about how I can reduce environmental damage when I go on holiday	.776			
I think about the environmental impact of services I use	.810			
When shopping, I rarely think about the environmental impact of the things I buy	-.528			
I am willing to reduce my use of air travel because of the environment	.484			
Experiencing different cultures is very important for me			.687	
Experiencing different cultures and destinations is more important than saving natural resources			.355	
Exploring new places is an important part of my lifestyle			.826	
It is easy for me to jump to a plane and go on a trip			.383	
I feel at home wherever in the world I go			.332	
Sometimes it is necessary to take a break from urban life			.272	-.295
I find it more interesting on a city street than out in the forest looking at trees and birds				.682
I would rather spend my weekend in the city than in wilderness areas				.790
There is evidence of global climate change		.754		
The main causes of global warming are human activities		.826		
Global warming will bring about some serious negative consequences		.858		

For pro-car attitude and suburban preference, the factor analysis was performed on a larger set of survey answers than presented below (Table 9), on statements about attitudes and preferences related to residential location and local travel. It produced a total of four factors: pro-car attitude, suburban preference, preference for shared housing and transport, and preference for nature and privacy. As only the first two factors are discussed in this compilation, and as the purpose of the table is to introduce what constitutes the relevant variables, they will be presented along with their factor loadings. The full table can be found in Appendix A in A2.

Table 9: Factory analysis of suburban preference and pro-car attitude from A2, Reykjavík

	Suburban preference	**Pro-car attitude**
I prefer to live in a suburban neighborhood, even if it means traveling longer distances	.883	
If I could live anywhere I would live in the suburbs	.827	
Suburban life is boring	-.71	
I like living in a neighborhood where there is a lot going on	-.509	
I don't mind traveling a bit longer for the everyday services I use	.458	
I appreciate tranquility and calmness in a residential area	.387	
I want to live close to the vast nature and recreational areas	.319	
Having shops and services within walking distance of my home is important to me	-.281	
The car is my preferred way of getting around the city		.903
I appreciate good travel connections by car		.679
I prefer getting around in an active way such as walking or cycling		-.599
I don't mind getting around using public transportation		-.548

2.6.2 Residential Zones

For A1, residential zones were taken from the GIS-based classification of Travel-Related Urban Zones from the Finnish Environment Institute, which is based on the distance from the center, population density, public transportation infrastructure, building stock, and jobs (Söderström, Schulman, & Ristimäki, 2015). Figure 2 shows the zones, but in A1 they were grouped into three zones:

- The central pedestrian zone and the fringe of the pedestrian zone became the *pedestrian-oriented zone*
- The pedestrian zones of sub-centers and intensive public transport zones became the *public transport-oriented zone*
- The basic public transport zone and the car zone became the *car-oriented zone*

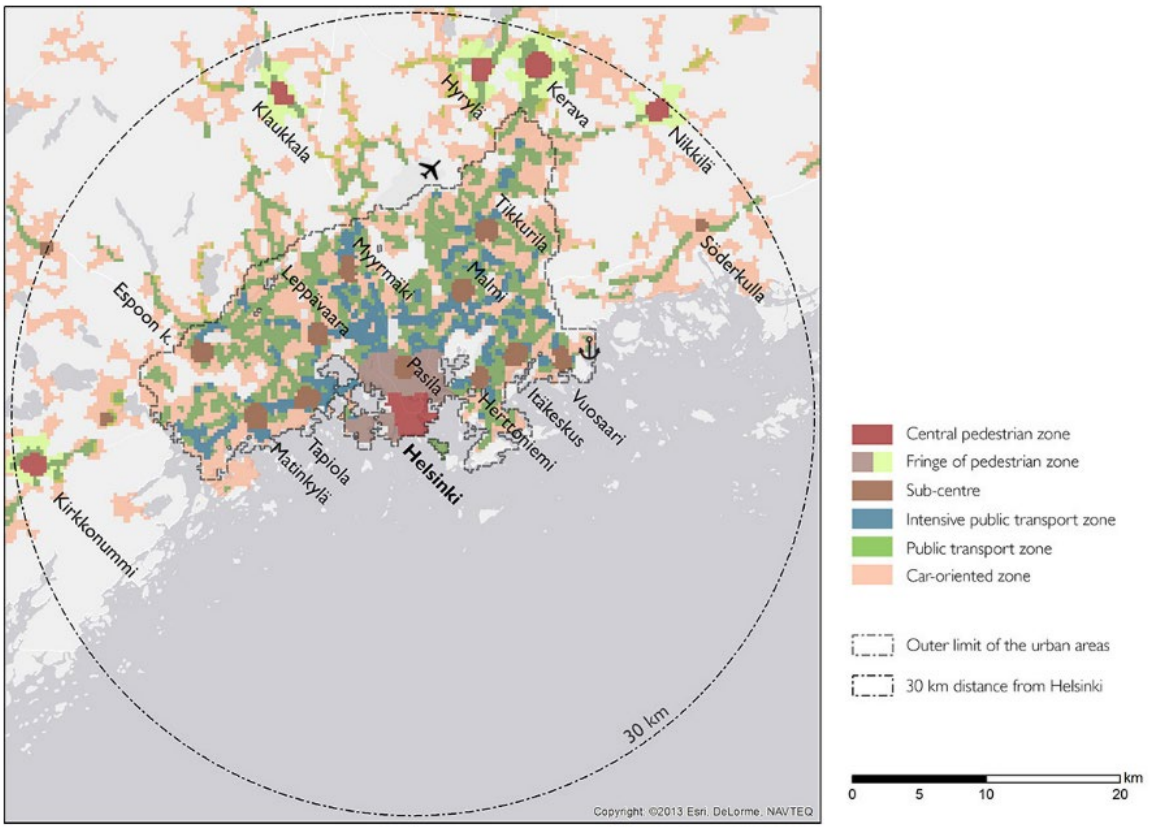

Figure 2: Travel-related urban zones of the Helsinki Metropolitan Area, taken from p. 23 of Söderström et al. (2015)

For A2, zones were calculated using a similar classification as performed by Söderström et al. (2015), based on distance from the commercial city center and access to public transportation, described in more detail in Appendix A4 in A2. The map showing the zones was first published in Appendix A of Czepkiewicz, Heinonen, Næss, & Stefánsdóttir (2020).

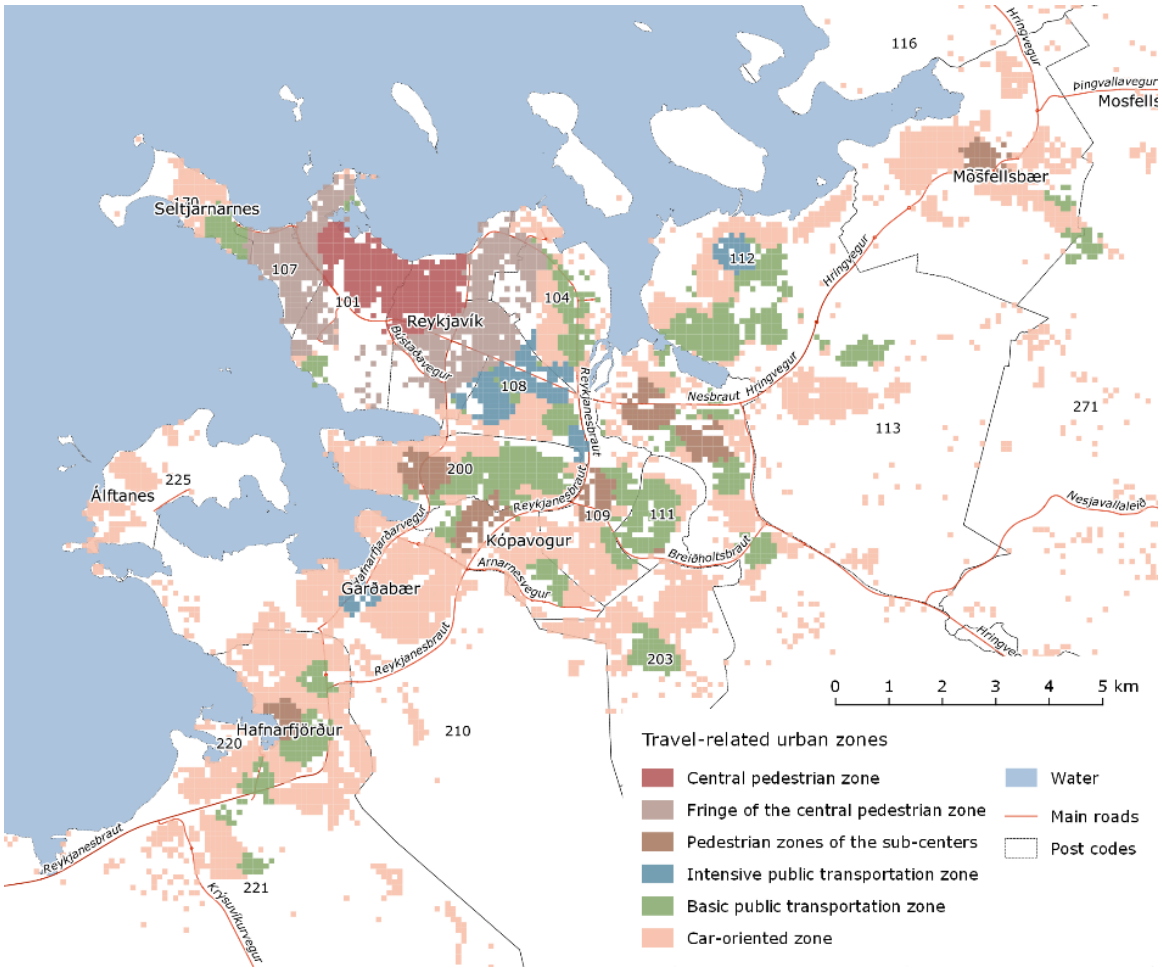

Figure 3: Travel-related urban zones of Reykjavík, taken from Appendix A of Czepkiewicz, Heinonen, et al. (2020)

2.6.3 Travel Emissions

To calculate emissions from trips taken by respondents (A1, A2), the distances were first multiplied by the frequencies provided in the survey. The GHG coefficient used to multiply the distances by was estimated using a life cycle assessment (LCA) approach, where both direct and indirect emissions are accounted for. Indirect emissions constitute for example production of vehicles and infrastructure construction. It was harmonized to Global warming potential over 100 years (GWP100) and short-lived climate forcers (SLCFs) were included in the assessment of flights. The emissions from trips were then split into three categories, and made up the variables local-, domestic-, and international travel emissions. The calculations of distances are explained in more detail in Appendix A of A2, along with other assessment details.

3 Results

This thesis set out to explore the spatial characteristics and drivers of environmentally significant behaviours, and barriers to PEBs. The main findings related to the three research questions were the following:

1) What are the spatial characteristics of PEBs related to produce, clothing, and household energy use, and of the environmentally significant behaviours related to local, domestic, and international travel?

> The spatial distribution of international and local travel emissions varied more strongly than those of domestic travel and PEBs related to household energy use, produce, and clothing purchases. High international and low local travel emissions clustered centrally, and those living in pedestrian-oriented zones engaged more in PEBs related to produce and less in PEBs related to household energy, compared to those living in the other zones.

2) What are the drivers of the environmentally significant behaviours related to local, domestic, and international travel?

> The quantitative analysis revealed that the main driver of PEBs related to clothing, household energy use, and produce purchases was PEA. However, PEA had no effect on emissions from travel. Drivers of local travel emissions were identified in quantitative analysis as distance from residential location to the city center, having children, pro-car attitudes, and suburban dwelling preferences. The drivers of domestic travel were identified in the qualitative analysis as a hectic urban life and inadequate quality of green areas. In quantitative analysis a preference for natural rather than urban areas, and access to a cabin, were drivers of domestic travel emissions, while car ownership was a strong predictor of whether the respondent took even a single trip in the surveyed year. The drivers of international travel emissions were cosmopolitan attitudes, language skills and high education in quantitative analysis, scarcity of cultural activity options in the local environment, and perceived well-being benefits of travelling abroad in the qualitative analysis.

3) What are the barriers to changing environmentally significant behaviours related to local and international travel?

> The main barrier to minimizing local travel emissions was a dominant car culture, while in the case of international travel, barriers included lack of knowledge about the climate change impact of flights, not feeling responsible for mitigation, and dominant social norms that dictate that travel abroad is necessary for well-being and socially expected.

These findings will be reported in more detail in the following subsections. The first subsection presents a brief summary of the key findings from the five articles that form this compilation (Table 10), followed by a section on the quantitative and spatial analysis from

A1 and A2. The third subsection presents the results from the qualitative and mixed-method analysis from A3, A4, and A5.

3.1 Summary of the Key Findings From the Five Articles

This section presents the relevant findings from the five appended papers. Table 10 presents each of the articles, their scope, and main findings related to the research questions of this thesis.

What can be seen from Table 10 is that in A1, there were significant differences in both PEBs (related to household energy use and produce) and environmentally significant behaviours (related to travel emissions) between residents who lived in different locations. Those living in central areas engaged in more PEBs related to produce and had lower emissions from local travel. Those living in more car-oriented urban structures were more likely to save household energy and have lower emissions from international travel. PEAs clustered centrally, and while they predicted PEBs, they did not predict lower travel emissions.

The results from travel-related emissions bore similar spatial patterns in A2, and in addition, it was identified that emissions from flights abroad were around triple that from local travel. Cosmopolitan attitudes, which clustered centrally, predicted higher emissions, and neither PEAs nor CCA significantly affected the emissions from travel.

In A3, it was identified that owning a car in Reykjavík was a social norm, and there was a strong car culture, with attitudes preferring cars and suburbs having a strong effect on the ownership beyond urban form characteristics. In many cases, respondents chose the current residential location based on preferred travel modes; if the preferred travel mode was a car, suburbs were chosen, and if it was walking, cycling, or using public transportation, the only location considered was the immediate city center. Having a child was considered as a driver both to acquire a car and to move to the suburbs.

A4 identified six themes of justifications to continue air travel despite high CCA, and the use of them differed depending on CCA. Those with the highest level of CCA, and the group who was willing to alter their behaviour, were less likely to use lack of knowledge or awareness, shifting responsibility, or carbon offsets as justifications. None were willing to give up on air travel, and a great emphasis was placed on the benefits of international trips abroad.

The push factors of long-distance travel, identified in A5, were a general lack of good quality green areas and a hectic urban life, irrelevant of the urban form characteristics in the vicinity of the home. Those preferring to reside in suburbs close to nature took more domestic trips to natural locations, and those residing centrally wanted to travel to larger cities. There was an indication of compensation for a lack of domestic travel due to car-less lifestyles of central dwellers, with international travel.

Table 10: The scope, data, and methods of articles A1, A2, A3, A4, and A5, along with the main results related to the thesis entity

Article	Scope	Main results
A1	How are urban zones and PEAs associated with travel emissions and PEBs related to clothing, produce, and household energy?	PEAs had higher values in pedestrian-oriented zones, and they positively influenced environmentally significant behaviors regarding household energy, clothing, and produce, but not emissions from travel. Those living centrally were less likely to participate in PEBs related to household energy use, and more likely to engage in PEBs related to produce purchases, than those living in car-oriented zones. They were also more likely to have travelled abroad in the surveyed year, while their emissions from local travel were lower.
A2	What are the predictors, structure, distribution, and levels of local, domestic, and international emissions?	The emissions from international leisure travel were on average around triple that of local travel, and six times higher than from domestic travel. The clustering of travel emissions was similar as in A1, and the attitude-behaviour gap was observed in all types of trips: local, domestic, and international. However, those with a high CCA had better language skills and a higher education, which was also true for those who participated the most in long-distance travel. In addition, the clustering of high international travel emissions in pedestrian-oriented zones could partially be explained by cosmopolitan attitudes, which also clustered centrally and predicted participation in international travel.
A3	How strong is the impact of urban form on car ownership compared to attitudes and socio-demographic characteristics, and what could explain the high rate of car ownership in Reykjavík?	Car ownership is a social norm in Reykjavík, and there is a strong car culture. Pro-car attitudes and suburban preferences influenced car ownership, and it was only in the immediate city center where urban form characteristics, such as access to public transportation and services, influenced less car ownership. The city center has a higher share of households without children, and there was a connection between car ownership, having children, and moving to the suburbs. Indications of residential self-selection based on preferred travel modes were detected, as interviewees often mentioned it as a reason to live in a certain place.

Table 10: The scope, data, and methods of articles A1, A2, A3, A4, and A5, along with the main results related to the thesis entity (Continued).

A4	How do the generally climate aware residents of Reykjavík justify their air travel, do these justifications differ depending on level of awareness, and is there an indication of willingness to reduce flying?	Six themes of justifications to continue air travel despite high CCA were identified: shifting responsibility, compensatory behaviours, lack of knowledge or awareness, lack of other options, benefits outweighing impacts, and carbon offsetting. When comparing groups of interviewees, those with the highest level of CCA and the group who was willing to alter their behaviour were less eager to use lack of knowledge or awareness, shifting responsibility, or carbon offsets as justifications. None were willing to give up on air travel, and those who were willing to minimize it to some extent did not differ in the CCA scores computed from survey data. These scores were most likely not able to capture a sense of urgency, responsibility, and deeper knowledge. A great emphasis was placed on the benefits of international trips abroad.
A5	What are the patterns and motivations for long-distance travel, and are they connected to urban form?	A general lack of good quality green areas and a hectic urban life were push factors of long-distance travel, regardless of residential location within the city. Preferences related to residential location on the one hand and leisure travel trips on the other were often related, and it was noticed that those residing in suburbs close to nature often reported taking more domestic trips to natural locations, while those residing centrally wanted to travel to larger cities. There was an indication that the car-less lifestyles of central dwellers hindered domestic travel, which was compensated for with international travel.

(Continued)

3.2 Quantitative and Spatial Analysis

PEAs were associated with PEBs related to clothing and produce purchases, as well as household energy use in Helsinki (A1), as the standardized beta coefficients were 0.447, 0.449, 0.282, respectively, all with p-values smaller than 0.001. Household energy use was however the least affected by PEA. This was potentially due to structural factors hindering direct control of household energy use, such as central temperature controls in apartment buildings. While high PEA clustered in city centers of both case study cities (A1, A3), living in the car zone was associated with more household energy saving in Helsinki (A1). Pro-environmental produce purchases were more likely in the central pedestrian zone, which could possibly be explained by easier access to shops with more sustainable produce. As the residents of the Helsinki central area had higher PEAs, and there may be better access due to higher density, these two factors likely influence each other through supply and demand; organic, local, and package-free food stores locating where the

environmentally aware customer base is. These three PEBs were only studied in Helsinki (A1). PEA did not predict lower emissions from travel, neither in Helsinki nor Reykjavík (A1, A2). Dense downtown living was associated with lower local travel emissions and higher international travel emissions, as can be seen in Figures 4-7 (A1, A2). High cosmopolitan attitudes also clustered centrally in Reykjavík, and were a significant predictor of international travel emissions in regression models (A2). However, the overlapping clustering of high flight emissions and high PEAs (A1, A2) does not necessarily mean that the high values belong to the exact same respondents. Figures 4 and 5 show the hotspot analysis from Reykjavík (A2), where blue dots signify clustering of low emissions, and red dots high emissions. The same pattern of clustering was found in Helsinki (A1) (Figures 6 and 7).

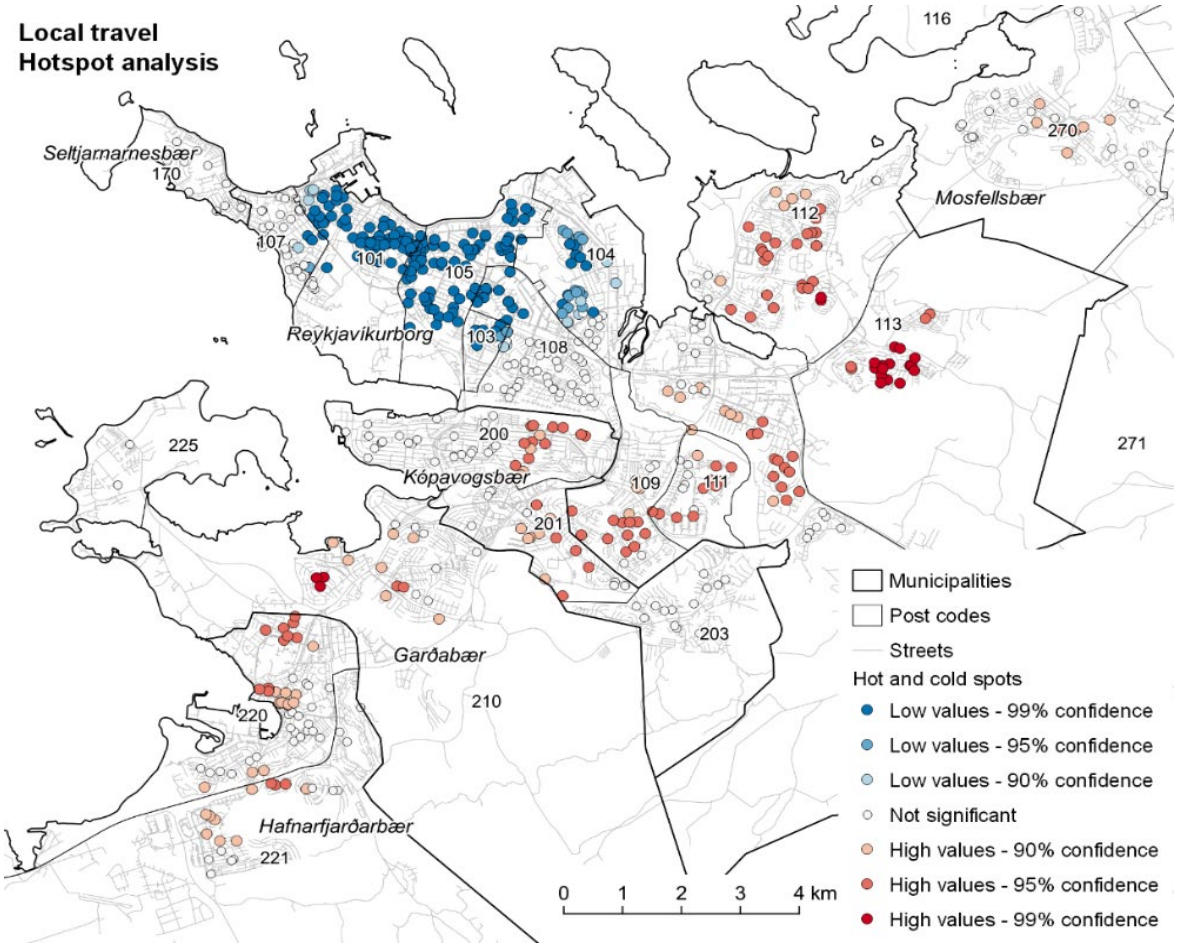

Figure 4: Hot spot map of GHG emissions from local travel, from Reykjavík (A2)

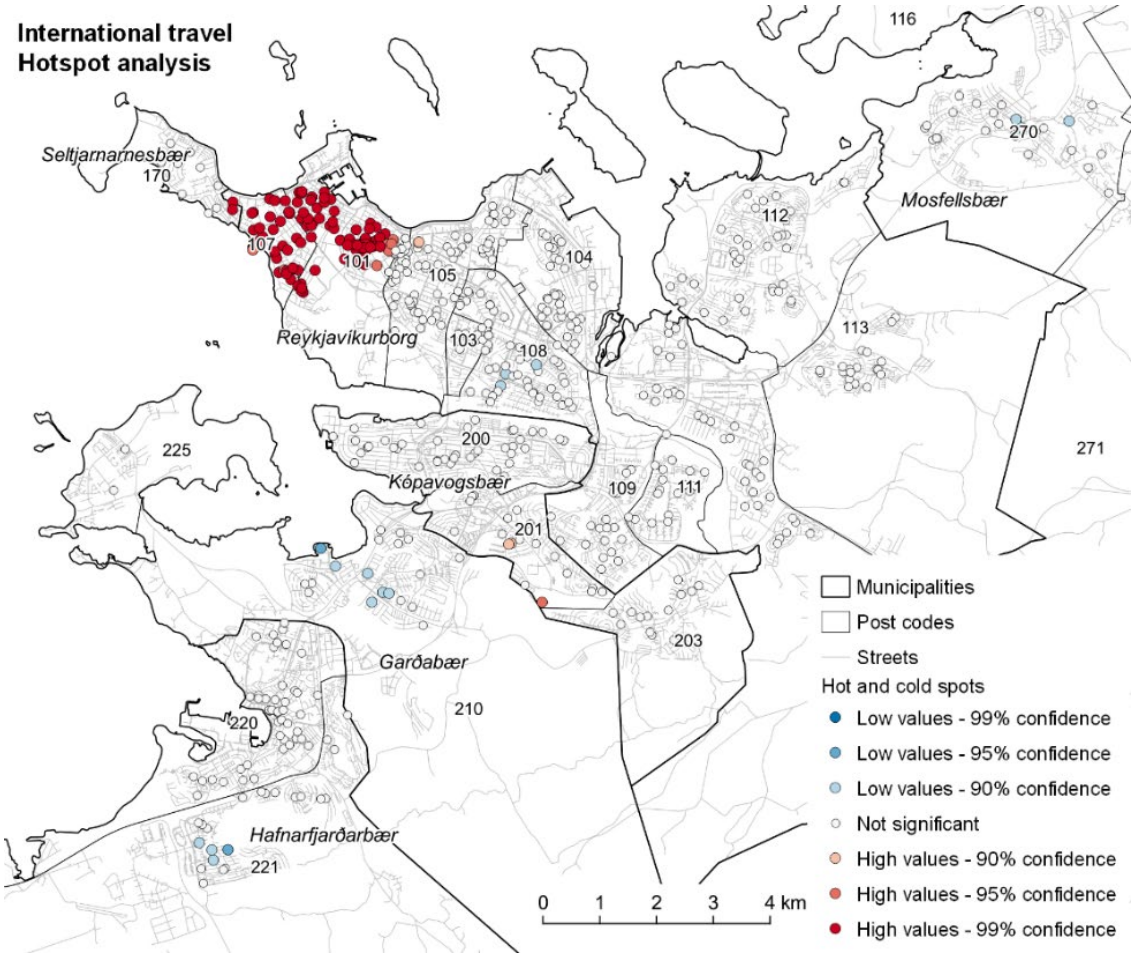

Figure 5: Hot spot map of GHG emissions from international travel, from Reykjavík (A2)

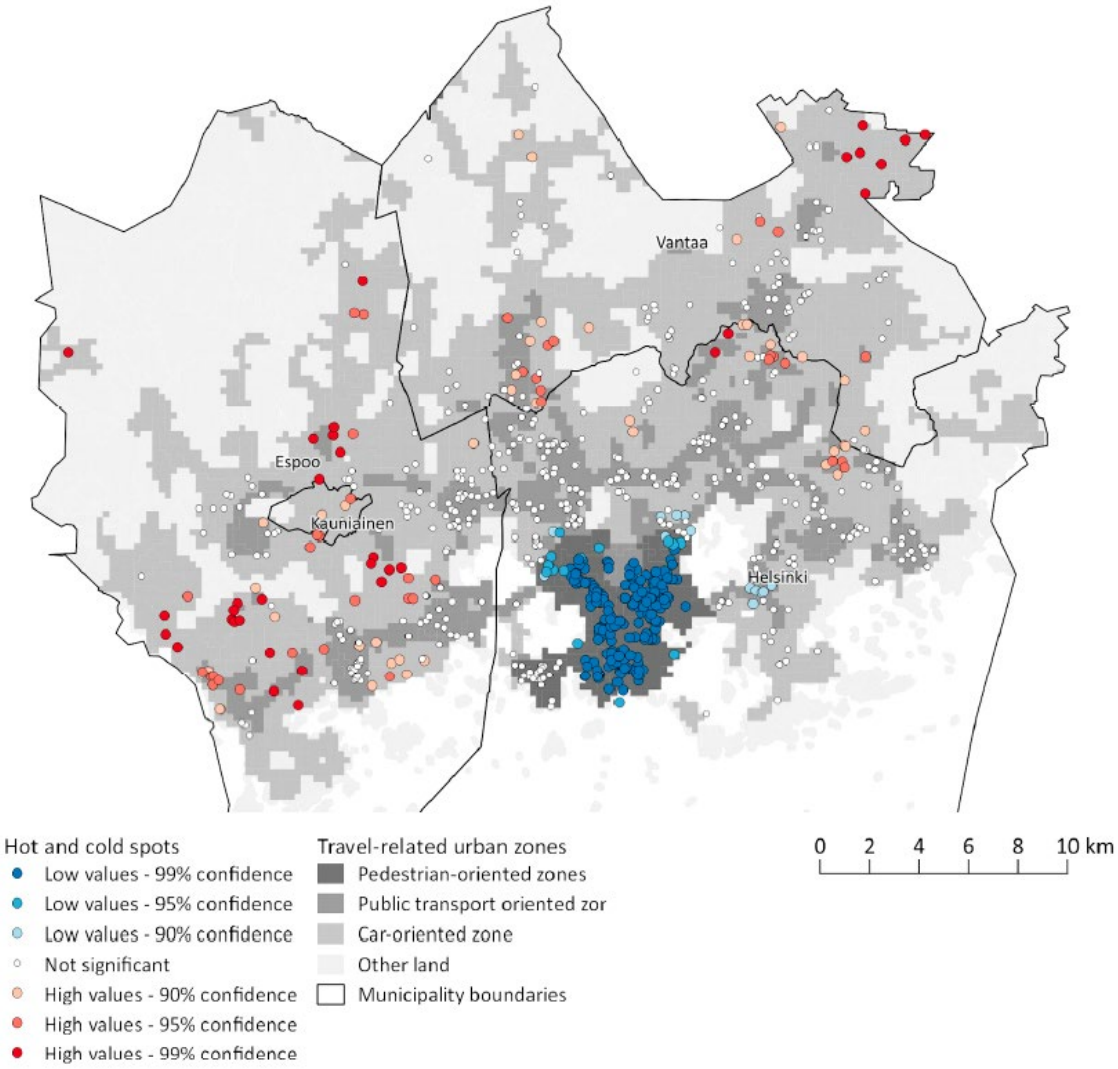

Figure 6: Hot spot map of GHG emissions from local travel, from Helsinki (A1)

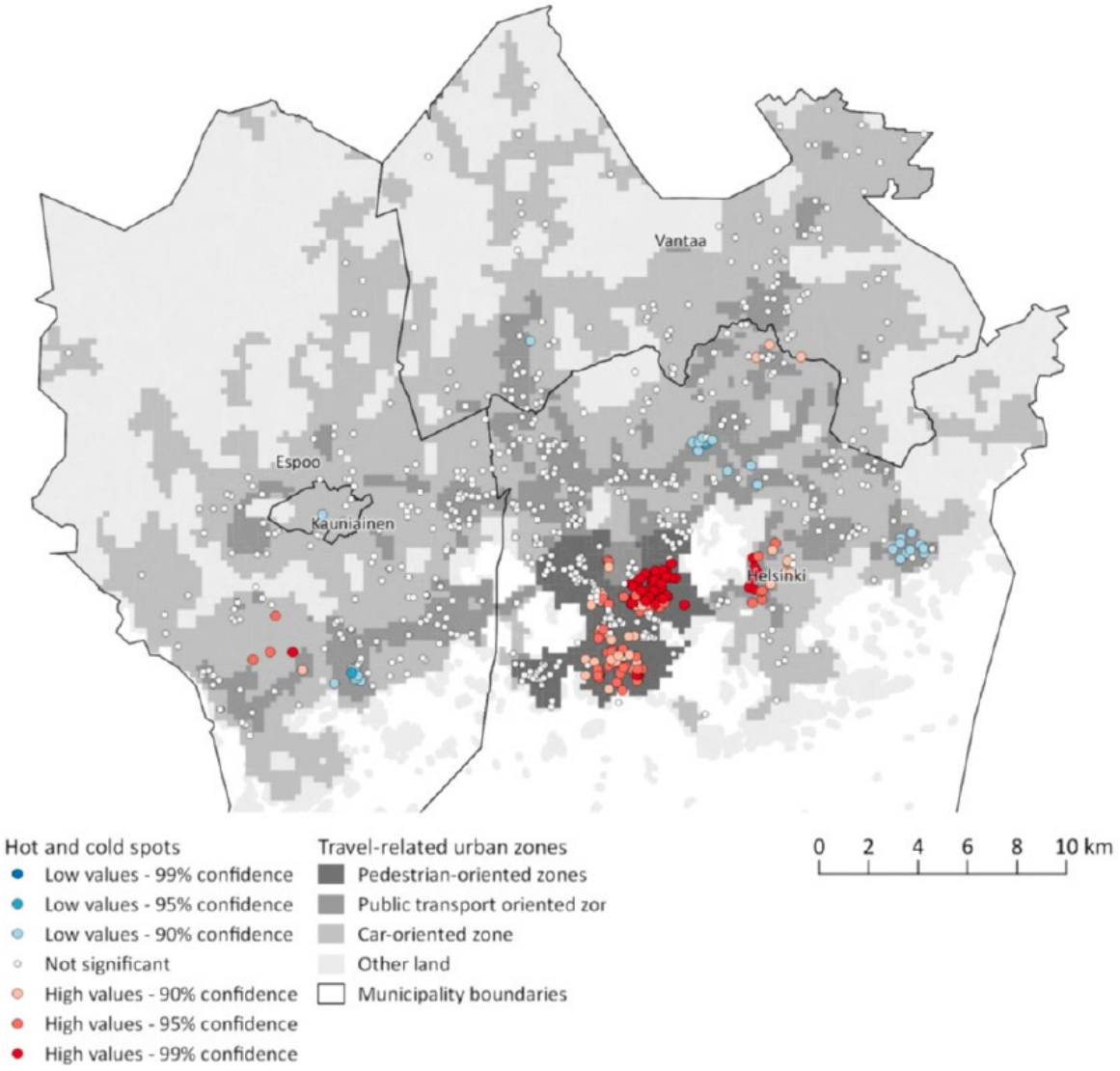

Figure 7: Hot spot map of GHG emissions from international travel, from Helsinki (A1)

Table 11 summarizes the findings from quantitative and spatial analysis from Helsinki and Reykjavík (A1 and A2, respectively). It presents the relevant spatial factors and the influence of PEA and CCA on each of the PEBs in question: clothing, produce, household energy, and the environmentally significant behaviours local, domestic, and international travel. The summary of findings includes results from both Helsinki and Reykjavík, although PEBs related to clothing, produce, and household energy were only examined in Helsinki. In addition, the Helsinki data contained only one measure of environmental attitudes (PEA), while in the Reykjavík data, two separate variables were considered, PEA and CCA.

Table 11: A summary of results of residential location and environmental attitude factors from A1 and A2

	Spatial factors	**PEA and CCA**
Clothing	Spatial analysis revealed no obvious clustering of PEBs related to clothing in Helsinki, although there was a hotspot around the northern border of the pedestrian-oriented zone. Residential zones could not predict this behaviour (A1).	PEA was a significant predictor, and by far the strongest of all other variables (A1).
Produce	Living in the Helsinki car zone predicted less PEB related to produce, and clusters of high produce-related PEBs were found in the central pedestrian zone (A1).	PEA was a significant predictor, and by far the strongest of all variables (A1).
Household energy	No significant clusters were found in the spatial analysis, but living in the car zone was associated with more PEBs related to household energy (A1).	Although PEA was the strongest significant predictor, the explanatory power was half that of the other two categories, clothing and produce (A1).
Local travel	Both in Helsinki (A1) and Reykjavík (A2), low local travel emissions clustered in pedestrian-oriented zones. Both residential zones (A1) and distance from the city center (A2) were significant predictors of both participation in, and amount of, emissions.	PEA predicted slightly lower participation in emissions in Helsinki (A1), but coefficients for other variables were higher, such as gender, income, and zones. In Reykjavík (A2), neither PEA nor CCA could significantly predict participation in or amount of emissions.
Domestic travel	Spatial analysis revealed no obvious clustering of domestic travel emissions, although a few small clusters of high emissions were found in the outskirts of Helsinki (A1). Neither zones (A1) nor neighbourhood greenness and access to a private yard (A2) could significantly predict domestic travel.	PEA did not affect participation in or amount of emissions (A1 and A2), but high CCA significantly predicted more emissions from domestic travel (A2).

Table 11: A summary of results of residential location and environmental attitude factors from A1 and A2 (Continued)

International travel	Although clusters of high international travel emissions were found in and around the city center in both Helsinki (A1) and Reykjavík (A2), the distance of the respondents' homes from the city center was identified neither as a significant driver of participation in international travel, nor of amount of emissions (A2), when cosmopolitan attitudes were added to the model. However, in Helsinki (A1), where cosmopolitan attitudes were not controlled for, those living centrally were more likely to have taken at least 1 trip in the surveyed year.	PEA (A1 and A2) or CCA (A2) could not significantly predict emissions from international travel, or whether or not respondents participated in travel that year. It was however noteworthy that CCA was positively correlated with participation in emissions (B=0.252), even though significance was lost after adding cosmopolitan attitudes.

(Continued)

While PEA was the main driver of PEB related to clothing, produce, and household energy use (A1), factors such as income, household type (A1, A2), and cosmopolitan attitudes (A2) drove international travel emissions. Car ownership was the strongest predictor of having participated in domestic travel emissions in Reykjavík, while access to a cabin and a preference for natural rather than urban environments significantly predicted the amount of emissions (A2). The explanatory power of this model was nevertheless low, which inspired further investigation of the motivations behind domestic travel. For local travel in Helsinki, the main drivers of lower emissions were residential location and income (A1), while in Reykjavík, although residential location did indeed affect the models, household type (family or couple) was the strongest predictor of participating in emissions and a pro-car attitude was the strongest predictor of amount of emissions (A2). This pointed to a cultural aspect specific to the Reykjavík population related to car ownership and use which warranted further study.

3.3 Qualitative Analysis

As high PEA could successfully predict PEBs related to clothing, produce, and household energy use (A1), and did not predict lower travel emissions (A1 and A2), the ABG related to travel emissions became a focus of qualitative analysis. The clustering of local and international travel emissions also raised questions on how factors related to urban form affect the emissions. The following subsections are dedicated to results from qualitative analysis on how urban form and PEAs affect travel emissions. Important to note, is that these findings are based on 21 interviews from one geographical location, and therefore are not generalizable, but instead provide insight into potential drivers of environmentally

significant behaviours and barriers to PEBs in this location, which can be compared to findings from other locations.

3.3.1 Local

It was evident from the quantitative analysis that emissions from travel are connected to urban form, but not as strongly to respondents' environmental attitude (A1 and A2). The only exception to PEA not predicting travel emissions was a significant negative association in Helsinki on participation in local travel emissions, so high PEAs could predict not using motorized travel, but could not predict amount of emissions. Other drivers were explored, and an investigation began into whether environmental attitudes were a factor in local transportation emissions, even though it could not be identified quantitatively in Reykjavík.

It was only in the immediate city center that respondents chose to live car-less, and access to public transportation was not of high priority when choosing a residential location elsewhere in Reykjavík (A3). This is highlighted with the following example quotes:

> *"...we have to have parking space as we have so many cars, so we could never go and live downtown Reykjavík ..." (ID 18, F36)*

> *"It was always in this area, the central area, where we could be car-less, or pretty much car-less, so it was very clear, ... I would preferably not want to go, you know, far outside a downtown core..." (ID 4, M29)*

Environmental considerations related to daily transportation were mentioned by some, but was not a strong enough factor in modal choice, as only one participant expressed that environmental reasons were the main decisive factor of giving up the car (A3):

> *"We are very environmentally conscious people. We just try to use ... bicycles." (ID 5, F29)*

Preferences for specific travel modes, culture and norms, weak public transportation image, and family structure seemed more influential than both urban form and PEAs (A3), which is demonstrated by the quotes below. However, the built environment may have shaped the preferences, culture, and norms, and therefore may indeed affect car ownership indirectly.

> *"I think having a car, it's like the norm. If you don't have a car you're like marginal. Since maybe that you don't have the money for it ..." (ID 19, F42)*

> *"... people are just really negative towards the bus often like at my workplace there are a few that are really negative, and they're like, very loud regarding it even though they have no experience of it, just hear it from the outside ..." (ID 4, M29)*

> *"... people find it maybe a liiiittle bit embarrassing to take the bus, . . . there is like some reputational risk hehe that accompanies it. ... I think this is the thought, and common, common thinking." (ID 6, M41)*

"[car-free living] is for the people who don't have children. I think it must be that way. It may be a choice for people who do not have children. But if you've got one and two and three kids, that's just somehow not a choice. I wouldn't understand how it works." (ID 7, F40)

3.3.2 Domestic

Although urban form had no clear quantitative connections to emissions from domestic travel, as the emissions neither clustered geographically nor did built environment variables predict them (A1 and A2), built environment characteristics were qualitatively explored in relation to compensatory travel (A5). It was observed that living in suburbs facilitated car ownership (see 3.3.1) and in turn domestic travel.

[We travel domestically] a lot less since we sold the car. We used to do it a lot…" (ID 5, F29)

Having access to a private garden could also lower the need to get out of the city, but those who choose a residential location in proximity to green areas and a private garden also have a preference for taking many trips out of the city.

"Yeah, so like, in the summer when I can actually be in my garden, like now it's just a thick layer of snow, I spend more time there, rather than taking these trips, I feel at least." (ID 20, F27)

Stimuli calling for leaving the city could be observed in all neighbourhoods, and therefore was a general characteristic of the urban environment rather than related to specific conditions connected to density, greenness, or distance to the city center (A5).

"It's just about cities, there's something like claustrophobia and an overwhelming feeling that I can't stand…" (ID 5, F29)

"I suppose it's just to escape for a bit from the tumult of the city… I feel like most Icelanders like getting out into nature a bit." (ID 1, M40)

3.3.3 International

The quantitative data (section 3.2) revealed that PEAs and CCA did not affect the emissions from international travel, and cosmopolitan attitudes were a significant predictor of whether or not the Icelanders had travelled that year, and speaking four or more languages predicted higher emissions (A2). This gave an indication that attitudes towards seeing new places and experiencing different cultures weighed higher than environmental attitudes, which warranted deeper analysis. Qualitative analysis focused on exploring how respondents expressed climate change concern while talking about trips abroad, and how they justified flights despite the concern. They were asked first to discuss their reasons for taking long-distance trips and the benefits they get from them, before being asked about what they think of the environmental impact of travelling.

The cognitive dissonance associated with travelling despite high CCA was alleviated with justifications for flying. These justifications were grouped into six themes (A4), which are listed below along with example quotes:

- Shifting responsibility

  "But I also feel like a large amount of the responsibility to change should be on massive corporations that do contribute the most. And I think it's almost like guilt tactics, and, you know, like, almost distract people and make them feel personally responsible. When really a large amount of it is on these big corporations and our unwillingness to regulate them." – (ID 17, F30)
- Compensatory behaviours

  "I try to make up for my pollution in other ways, you know, like, food waste. ... I don't want to buy fruits or vegetables that are made far away if I can buy something that's grown here in Iceland ... Even though it's more expensive." – (ID 21, F42)
- Lack of knowledge or awareness

  "I mean I, just live in that way and live in such a wonderful country that I'm lucky to not have to think about it ... of course everybody has to think about it, but I'm just not in a place that it, that you feel the effects right now, so you just let yourself, but maybe it would be completely different if I was in a completely polluted place somewhere out in the world, then you'd be like, more cautious regarding this." – (ID 4, M29)
- Lack of other options

  "I live on an island. Even though some activists and nature lovers have stopped using airplanes, it's maybe not realistic for me as I live on an island." – (ID 13, F39)
- Benefits outweighing impacts

  "If I didn't get so much out of it mentally, I wouldn't go. Then I wouldn't have this carbon footprint. And I have a massive guilty conscience about going. But at the same time, I often am depressed and sad, and I always have to do something for myself. And that's why I go." – (ID 13, F39)
- Carbon offsetting

  "It just doesn't make any difference to my bank account, and I think it's, I think it should be mandatory for people to do this." – (ID 8, F38)

The use of justifications differed depending on respondents' level of CCA and willingness to reduce air travel; those with more extensive knowledge of environmental issues (not just based on the quantitative CCA scores, but based on background information from the interviews) were less likely to use the lack of knowledge or awareness, shifting responsibility, or carbon offsets as justifications to continue travelling by air. Still, there were respondents observed with high scores who would rather offset their emissions than change their behaviour or report little knowledge of the specific impacts of flights, but those were neither educated in the environmental field nor were activists, which clearly shows that the quantitative survey data could not sufficiently capture the highest level of concern and environmental knowledge. These three themes of justifications were also less likely to be used by those who were willing to reduce their air travel, whether they had extensive knowledge or not. For example, this respondent mentions travelling *less*, but available data lacks information on *less* than *what*.

"Yes, do it with more care, start travelling maybe less times but for a longer time..." – (ID 10, F37)

Although quantitative data showed a positive (however not significant) relationship between CCA and emissions from flights, qualitative data showed indications that CCA, especially on the impact of flights, does indeed influence behaviour, but the differing baseline emission levels of survey participants, before behavioural change, make it difficult to detect quantitatively. This is demonstrated for example by this particular respondent, who was an environmentalist by profession:

> *"I decided some years ago, I won't go like to India again or I would probably never see Australia, which is fine. I mean, I don't need to go there." – (ID 18, F36)*

Another reason might be that there are simply too few people who have already reduced their travel, although they state willingness for future reduction.

The impact of urban form on international travel was only identified through indirect causal mechanisms. Living in the city center facilitates a car-less lifestyle (A3), but being without a car restricts domestic travel (A5). The data suggested a degree of substitution between domestic and international travel in which time and/or money not spent on domestic trips or car purchase and maintenance are spent on international travel. When discussing international travel, this car and cabin owner said the following:

> *"The salary isn't too high so you know I haven't, or you know I would have to save up, scrape together for a trip, and so that maybe reduces the interest somewhat." (ID 1, M40).*

Although not mentioned directly, there were indications of a relationship between not having access to a private garden and more frequent international travel. Some respondents who did not possess one and stated that they did not feel the need to have one expressed disinterest in travelling domestically and immense interest in international travel, especially to other larger cities. That connection is however also likely to go the other way; those who place importance on private gardens also prefer nature trips, and those types of trips can be satisfied within the country (A5). The quantitative analysis revealed that household type was associated with international travel, as families with a child or children were less likely than couples to have participated in the past year (A2), which in turn indirectly connects to urban form, as families tend to locate away from the immediate city center (A3). Families are also more likely to be car owners (A3), thus triggering the mechanism above. Lack of cultural diversity, such as in relation to food, museums, concerts, and architecture, could also be identified as reasons to go abroad to seek this diversity (A5).

> *"The motivation with most people around me is to explore and experience something new and try something else than you get here in this country." (ID 4, M29)*

4 Discussion

This section first lays out the overall contribution of the thesis, split by spatial characteristics, drivers, and barriers, and the main findings are then positioned among previous literature. The reliability and validity of the research are discussed, followed by suggested future research directions and a conclusion.

4.1 Contribution of the Thesis

This thesis set out to answer the questions:

1. *What are the spatial characteristics of PEBs related to produce, clothing, and household energy use, and of the environmentally significant behaviours related to local, domestic, and international travel?*
2. *What are the drivers of the environmentally significant behaviours related to local, domestic, and international travel?*
3. *What are the barriers to changing environmentally significant behaviours related to local and international travel?*

The subsections below first discuss the main results, split by each of the research questions.

4.1.1 Spatial Characteristics

Those living in the Helsinki car zone engage in more PEBs related to household energy saving and less related to produce purchases, which indicates that urban form affects PEBs regardless of PEAs, potentially through urban form related availability of infrastructure and services, as well as through differing possibilities for engagement. However, spatial distribution of local and international travel emissions varied more strongly than the spatial distribution of PEBs. There were clusters of low local and high international travel emissions in pedestrian-oriented zones in both samples, as well as clusters of high PEAs. The clustering of local travel emissions was expected, but the clustering of international travel emissions less anticipated, especially due to the high PEA clusters in similar areas. Cosmopolitan attitudes clustered in pedestrian-oriented zones in Reykjavík, which partly explained the high international travel emissions. In such affluent samples there was bound to be strong evidence of residential self-selection, especially in Reykjavík where housing prices do not differ as much between neighbourhoods as in other metropolitan cities. So, although there may be some spatial factors that hinder or facilitate behavioural choices, residents are aware of these factors before choosing a place to live, as preferences for residential neighbourhood were often dependent on preferred daily travel modes. It can be deduced that preferences weighed heavier than urban form, as the pro-car attitude standardized beta coefficient was higher than that of distance of residential location from city center in Reykjavík when assessing local travel emissions. However, as urban form shapes travel mode preferences, these factors of influence are interlinked. There are still

unknown urban form-related factors of influence regarding international travel. The clustering of high emissions centrally is clear, but although cosmopolitan attitudes were identified as a predictor, the explanatory power of the models was low. Qualitative analysis identified some indirect influences of urban form through car ownership and access to a private garden (which drove domestic travel in almost a reverse manner), and cultural deficiencies in the local environment.

4.1.2 Drivers

While high PEAs did not result in lower emissions from travel, they drove PEBs related to clothing, household energy use, and produce purchases. However, the environmental significance of the behavioural changes in the three PEB domains was not quantified, and the climate mitigation potential of them can be doubted. Travel emissions were however quantified, and were on average 4,5 tons CO_2eq per capita annually. That is just half a ton shy of filling the whole lifestyle-related per capita carbon budget, suggested by (Akenji et al., 2019), which will decrease to a mere ton by 2050. A notable driver of local travel emissions, which was on average around a ton per capita, was the distance from residential location to the city center. The further away one resides from the city center, the more they drive. However, the analysis performed on the Reykjavík data revealed that there are many other factors that influence the emissions, beyond the direct effects of urban form. Life course situations such as having children or planning for them drive people to purchase vehicles, as they feel that organizing their everyday life with a child, in this particular urban space, is impossible without owning one. Workplaces and childcare facilities are difficult to reach with any other travel mode within stated time constraints. Pro-car attitudes and suburban dwelling preferences were also drivers of emissions, showing that oftentimes it is an informed decision to reside in areas which require car ownership, which in turn is a preferred travel mode regardless of urban form characteristics. For domestic travel, the drivers seemed to be related to a general stressful urban environment and lack of quality outdoor recreational areas, which shows the importance of considering a larger area than the location of residence when assessing how urban form affects domestic travel emissions. Cosmopolitan attitudes, language skills, and high education predicted international travel emissions, while some of the identified drivers were lack of cultural activity options and perceived well-being benefits of travelling abroad.

4.1.3 Barriers

The barriers to changing environmentally significant behaviours towards behaviours with lower environmental impacts are plentiful. Related to local travel, the barriers are mainly cultural, such as a poor image of public transportation and the social norm status of cars, but having children is also seen as a barrier to a car-less lifestyle. Not possessing a private vehicle can be a barrier to domestic travel, although limiting domestic travel can be a relevant mitigation strategy, as some of those who participated less in it compensated for it by travelling more abroad. There were indications of the monetary rebound effect related to car ownership, as some who owned a vehicle and a cabin said they would need to save up for a holiday abroad, although it was mainly due to preferences such as wanting to experience different cultures, which cannot be satisfied within the country. With international travel, barriers included lack of knowledge on the climate change impact of flights, not feeling responsible for mitigation in this domain, and the immense value placed

on the well-being benefits of leisure travel, which in turn can be associated with dominant social norms.

Figure 8 presents a mind map of the different influencing factors leading to flight behaviour impact, based on both the findings from this thesis and literature review. It shows that although an individual is aware, knowledgeable, senses the urgency of climate change, and accepts responsibility of own actions, there are many other factors of influence. Lock-ins, such as having friends or family members in other countries, other attitudes such as cosmopolitan attitudes, social norms that place long-distance travel as a necessary for sufficient living standards, and the availability of alternative travel modes such as a fast and efficient train system, are also influencing factors. Even when those aforementioned factors come together and create behavioural intent for mitigation, compensatory behaviours and offsets can act as barriers to behavioural impact, as well as old habits which make changing more difficult. In addition, although the behavioural intent is to decrease the number of annual trips, the previous baseline behaviour before desiring change has a significant impact on the amount of GHGs emitted. It is therefore evident that assessing the relationship between attitudes and emissions will result in an extensive ABG, if all these influencing factors are not considered.

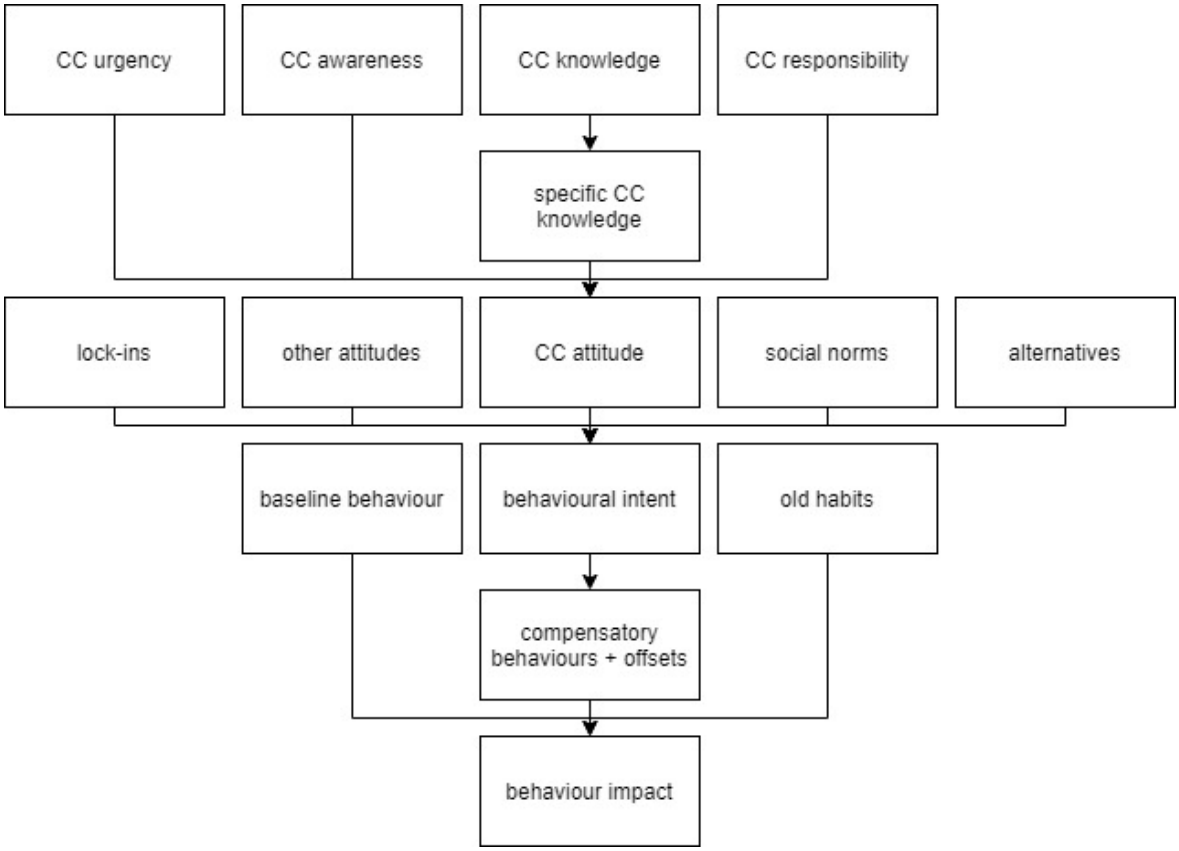

Figure 8: Mind map of influencing factors of behavioural impact

4.2 Positioning Among Previous Literature

In general, our findings on the connection of PEBs related to clothing, produce, and household energy use were similar to those in previous studies (Bronfman et al., 2015; Bruderer Enzler & Diekmann, 2015; Díaz-Siefer et al., 2015). Low-cost and easy-to-change behaviours tend to have a smaller attitude-behaviour gap (Steg & Vlek, 2009), and switching to other products in the same product category, such as to second-hand clothing or to organic produce, usually does not require major lifestyle changes. The largest ABG was with the PEB factor related to household energy use, and previous literature on urban form-related differences in monetary incentives and opportunities to save energy could potentially explain that (Heinonen & Junnila, 2014; Kyrö et al., 2011). High PEBs related to produce clustered in the center, where people were more likely to purchase organic, package free, and local produce, which can potentially be explained by better access to sustainable produce in dense agglomerations (Kennedy, Krogman, & Krahn, 2013). However, the actual environmental impact reduction potential of these produce-related actions may not be high, and therefore this discussion will have a main focus on travel, and finally air travel behaviour, as the emissions from flights were triple that from local travel in the Reykjavík sample.

PEAs have been associated with less car ownership and use (Anable, 2005; Stewart Barr & Prillwitz, 2012; Flamm, 2009). This was in line with our results for Helsinki with regards to ownership, but not use, and not true for the Reykjavík sample at all. As pro-car attitudes were strong predictors of car use in Reykjavík, and a dominant car culture clearly identified through qualitative analysis, it seems that other attitudes and norms, unrelated to environmental concern, weigh heavier when it comes to local travel behaviour. Our results which showed clusters of low local travel emissions in the city centers were in line with previous research (e.g. Næss, 2012; Næss, Peters, Stefansdottir, & Strand, 2018; Waygood, Sun, & Susilo, 2014; Zahabi, Miranda-Moreno, Patterson, & Barla, 2015), but our analysis showed strong influence from several other factors not directly connected to urban form, such as a car-oriented culture, general preference towards driving or living in suburbs, and household type. However, as discussed in A3, it can be argued that car-oriented culture is a result of the built environment. A car-oriented culture can be the consequence of a strong emphasis in urban planning on expanding road infrastructure for private vehicles, with less priority placed on alternative transport infrastructure such as well-connected cycle paths, good public transportation, and walkable streetscapes, combined with urban sprawl and segregation of places for living, shopping, and working. This type of urban planning was dominant in the study area for decades (Valsson, 2003), and the focus towards densification has only just recently shifted (Reykjavík City, 2014). The new planning emphasis on creating better conditions for alternative transport modes has not gained a large following among residents, many of whom claim that there is an ongoing “attack against the private car” (i. “aðför gegn einkabílnum”). This is a good example of how individuals contribute to sustaining car cultures, as pointed to by Mattioli et al. (2016) in relation to the macro-approach to car-dependence. In addition, little competence (Mattioli, Anable, & Vrotsou, 2016) with alternative travel modes was detected, as those who did not actively use public transportation were the ones who discredited it as a viable alternative. As urban form affects culture and culture in turn affects preferences, it is difficult to separate them from one another and assess any independent influences they have on local travel emissions. Unfortunately, recent literature shows that COVID-19 had unfavorable outcomes for public transportation utilization, as public transport users were found to be

over thirty times more likely to switch to a different travel mode than car users (Dingil & Esztergár-Kiss, 2021). This could potentially contribute to sustaining the car culture in Reykjavík, and add to the long list of justifications to carry on driving.

With domestic travel, previous studies have found that emissions increase with distance of residential location from the center (Næss, 2016), but although a few clusters of high emissions in Helsinki were found on the outskirts, regression analysis identified no urban form-related factors of influence. This was partly explained by qualitative analysis; urban stress and low-quality green areas were identified as drivers of long-distance travel, but these drivers were not concentrated in any specific part of the city. They were rather found throughout it, explaining why previously suggested theories of compensation (Holden & Norland, 2005; Næss, 2006; Strandell & Hall, 2015) were not visible in our quantitative data. General annoyances related to city life which extend past the residential location to the broader activity spaces, defined as all the places a person has contact with in daily life (Golledge & Stimson, 1997), should therefore be included in future studies. Czepkiewicz et al. (2020) found with the same data utilized in A1 and A2, that more neighbourhood greenness, a variable not included in the assessment in A1, was associated with a lower number of domestic trips in Helsinki, but not Reykjavík (Czepkiewicz, Klaas, et al., 2020). Facilitators and barriers of car ownership, which were related to urban form for example through limited parking in downtown, influenced domestic travel. In Reykjavík, access to a summer house and a preference for natural environments predicted more domestic travel (A2). Qualitative data revealed that those who most value the natural environment often prefer to reside outside of the city center, which was also identified quantitatively for both Helsinki and Reykjavík in Czepkiewicz et al. (2020). These preferences and the subsequent residential self-selection are more likely to be drivers of domestic travel than urban form itself, which is in line with previous studies (Czepkiewicz, Klaas, et al., 2020), and the fact that many of these variables were controlled for in the regression explains the lack of relationship between urban form and domestic travel.

The results on international travel were in line with previous research which suggests that high PEAs are not related to lower emissions from international travel (Alcock et al., 2017), and high emissions cluster in central parts of cities (Czepkiewicz, Heinonen, et al., 2018; Czepkiewicz, Ottelin, et al., 2018; Holden & Linnerud, 2011; Holden & Norland, 2005; Næss, 2006). Cosmopolitan attitudes, which include the importance of experiencing different cultures and new places, also clustered centrally and were a significant predictor of international travel emissions in regression models (A2). While this influencing factor of international travel has been speculated upon in previous studies (Czepkiewicz, Heinonen, et al., 2018; Holden & Norland, 2005; Næss, 2006), and support has been found for cosmopolitan identity predicting flight kilometers (Oswald & Ernst, 2020), more research has been called upon to study the association. The immense value of travel was clearly seen as a major justification to continue air travel in qualitative analysis (A5), which at least partly confirms the connection. However, it is still unclear whether cosmopolitan attitudes develop through living in a centrally located area, or if individuals with this outlook choose to relocate more centrally because of it. The urban environment, or the living standards contained within it, can change how one perceives necessities (Aro & Wilska, 2014). Thus, the value placed on holiday travel, marking it as necessary for well-being, could in the end be connected to the urban environment and the norms perpetuated through urban form-related measures. These urban form-related measures could for example be density-driven economies of agglomeration, with the resulting high

consumption. In previous literature, holiday travel has been highly valued because it is objectively related to freedom (Becken, 2007), but although freedom is a difficult concept to unpack, it can be speculated upon if it can genuinely hold true that individuals did not feel truly free before frequent flying became a norm.

The justification strategies used by respondents were similar as in previous studies (e.g. Juvan & Dolnicar, 2014; Lorenzoni et al., 2007), but the analysis revealed a stronger emphasis placed on the benefits of air travel than in previous studies, potentially due to the remote location with harsh weather and a lack of alternative transport modes off the island. It could also be connected to the dominant social norm practices regarding flights in this affluent location, as a recent study which examined the effect of cosmopolitan identity, which included social norms related to travel, found it to be a significant predictor of international flight travel (Oswald & Ernst, 2020). International leisure travel has become necessary for well-being and sufficient living standards. As "internationalization" is increasing, with many individuals having friends and family living abroad with whom they want to maintain relationships, long-distance travel may become even more of a necessity, or a *need* rather than a *want*, as friendship and family are key for satisfying basic human needs (Mattioli, 2016). It may be that in Reykjavík the "internationalization" is greater, or the norms connected to flight behaviour even stronger in this location than in others, where people have successfully managed to distance themselves from the norms and are therefore, among other things, able to reduce holiday travel (Büchs, 2017). The data were collected before COVID-19 travel restrictions were put in place, and results may differ if the study is repeated post-pandemic. A recent study by Isaac & Keijzer (2021) found that if an individual's travel intentions were limited due to COVID-19, the restrictions can act as a motivator for future travel. However, high risk perception can still lead individuals to choose domestic travel destinations rather than international ones, even after restrictions are lifted. Self-enhancement values and openness to change are still key predictors on whether individuals plan for future travel (Isaac & Keijzer, 2021).

The use of compensatory green behaviours to justify flights was used by respondents with high CCA, contrary to findings from Kaklamanou, Jones, Webb, & Walker (2015). However, the respondents with the most knowledge of environmental issues showed understanding of the detrimental effects of flight behaviour while discussing the compensation. They felt that it did not null out the impact of their flight behaviour, but instead they felt that they deserved leisure travel because they were environmentally better in other lifestyle domains. It has been reported that for those with limited knowledge on climate change, shifting responsibility onto the government is the most used justification (Dickinson et al., 2010), which fits well with our results that shifting responsibility was least likely to be used by the most climate change aware. That is not to say that governments should not be responsible for action, to the contrary. Individuals should not bear the sole responsibility of mitigation, as that creates inaction in policy. One of the main discourses of climate delay is this shifting of responsibility, either between the individual realm and the government, or between countries (Lamb et al., 2020). It is therefore crucial that all actors share responsibility; those who have the ability to mitigate take action, and avoid pointing fingers at larger emitters.

4.3 Validity and Reliability of the Study

Validity and reliability measures are used to evaluate the quality of studies. While validity refers to whether or not the research has successfully and accurately measured the intended phenomenon, reliability relates to the reproducibility of the results (Heale & Twycross, 2015). Mixing of methods in itself can act to increase the validity and reliability of research, as it "*allows us to balance the strengths and weaknesses of each approach*" (Abowitz & Toole, 2010, p. 108) and allows reflection on what can be learned from different kinds of data. Although the findings from this multiple case study research are not necessarily generalizable, especially not to populations with very different socio-economic backgrounds, they are still meaningful and have successfully provided some insight for each of the research questions. As put by Flyvberg (2016, p. 10): *"That knowledge cannot be formally generalized does not mean that it cannot enter into the collective process of knowledge accumulation in a given field or in a society."*

As this thesis draws on multiple analysis and data curation methods, following proven and tested procedures and theories every step of the way, in collaboration with experienced researchers, the overall research is abundant in rigor. The remainder of this section discusses some of the procedures taken to ensure validity and reliability of the research.

For the quantitative analysis, various diagnostics were used to test the validity. For the factor analysis, a Kaiser-Meyer-Olkin and Bartlett test was used to test the adequacy of sampling, and the eigenvalue was checked along with the percentage of explained variance. Spatial autocorrelation of standardized residuals, residual analysis, and collinearity diagnostics were performed on regression models to test heteroskedasticity, and Variance Inflation Factors were examined to test multicollinearity. The samples used were random and geographically stratified.

For the qualitative data, constructive procedures to ensure rigor were used during data curation and analysis. Each interview, although following the interview protocol, shifted the main focus based on the respondents' answers to questions. This form of listening to the data showed responsiveness of the investigator which is essential for reliability and validity. Another verification strategy of qualitative data is iteration (Morse, Barret, Mayan, Olson, & Spiers, 2002). The theory development was iterative; quantitative data and literature review informed the initial interview protocol, while pilot interviews informed the final interview protocol, which also took on minor changes during data collection. After data collection, the data analysis was based on a set of questions, developed by literature review and previous quantitative results, to answer various research questions, some of which arose after initial transcriptions and listening to the data. Independent cross checking was done, and no research questions were left interpreted by solely one member of the research team. In addition, when in doubt over the meaning behind certain statements or thoughts, the audio and the untranslated transcripts were revisited to ensure accurate understanding.

While the quantitative data was a random geographically stratified sample, the qualitative data was purposefully selected to reflect theoretically relevant categories, which are seen as key requirements for each method's sample selections. Objectivity and verifiability are also key components of reliability of qualitative studies (Weis & Willems, 2017). Subjectivity was minimized with more than one member of the research team interpreting

and analyzing the data, and as all audios, transcripts, translations, and interpretation schemes were well documented, verifiability and transparency were assured.

Although correlation claims cannot be made with qualitative methods, they provide indications of such correlation which can later be studied with quantitative methods. Theoretical generalization is however possible with qualitative interview materials (Weis & Willems, 2017).

The mixed-method approach was not specifically applied to compare the quantitative and qualitative data, it was nevertheless noticed that despite the quantitative data showing no effect of PEAs on travel emissions, there were indications in the qualitative data that many respondents changed their behaviour due to PEAs. This divergence was tackled with reconciliation (Pluye, Grad, Levine, & Nicolau, 2014), as the data enabled the suggestion of a new framework for analyzing how attitudes affect behaviours. In addition, the inclusion of other socio-demographic drivers of travel emissions are suggested, as well as applying longitudinal methods; although respondents reported that they had minimized travel due to environmental concern, the lack of a baseline travel emission level to compare to was problematic. Respondents had different norms related to travel, and some may have minimized but still had higher emissions than respondents who had not altered their travel behaviour at all.

In general, the validity of the research is considered good, as it has successfully and accurately measured the intended phenomenon. The reliability, or in other words the reproducibility of the results, is high in this particular geographical context, with this studied age segment. In addition, the studied cases add to the existing knowledge in other locations, and thus improve the reliability of previous findings which were in line with those of this study. Together, they can form theories (Eisenhardt & Graebner, 2007).

4.4 Future Research Directions

Although the quantitative studies (A1, A2) strove to include all relevant factors of long-distance travel in the survey, the qualitative analysis, along with other studies published since data collection, have revealed additional factors to be considered and added to future quantitative studies.

Dispersed social networks, often as a consequence of migration, have been found to influence travel emissions (Mattioli & Scheiner, 2019), and an indication of these effects was found in our data. A highly aware respondent who had migrated to Iceland would never give up travelling home to see her family, although she acknowledged that her migration was not a good environmental decision. In addition, she stated willingness to quit traveling to Asia or Australia, showing a general commitment to minimized travel behaviour which could not be applied to travels to her country of origin. Travelling home to see loved ones may have become a need satisfier for her, as illustrated by Mattioli (2016). It is therefore crucial for quantitative data exploring the attitude-behaviour gap in aviation to contain information on migration to control for its influence. In general, the regression models on long-distance travel had low explanatory power, so it was evident that there are many unidentified variables. Potential aspects to include in future quantitative studies would be local environmental factors such as work-related stress,

commuting stress or annoyances such as noise pollution, attitudes related to a sense of urgency regarding climate change, acceptance of personal responsibility, views on the efficacy of individual action, and knowledge of flight-specific climate change impact, relative to other consumption categories.

Qualitative studies should set out to explore the perceived value of international travel and the importance of it for well-being, and quantitative surveys and geographical analyses could then be used to see if these values differ in space. This could be done both across countries (e.g. resulting from differing cultures, norms, weather) and within cities (e.g. resulting from local mobility, access to green spaces, recreation, and services). An aspect to add to this would be to study how preferred trip types differ depending on residential location, and how trip preferences match with home location preferences. Such results could provide valuable information on deficiencies in the local environment resulting in travel as a need satisfier, but would require the inclusion of household situations to distinguish between personal preferences and the preferences based on choices available, as it was noticed in the data that many mentioned desired future travel destinations based on which were the most comfortable to travel to with children or grandparents.

As no willingness to quit air travel was found in our sample, and our data had relatively few car-less households, purposeful sampling of these two groups in this location, which has both a dominant car culture, harsh weather, and no viable alternative travel modes off the island, could prove fruitful. Research on the decision-making process and overcoming the barriers could yield more information on what is needed to reach the tipping points of giving up on cars and aeroplanes. In addition, any scholar who has the opportunity to apply longitudinal methods to previous studies on car ownership and flight behaviour is strongly encouraged to do so, as studying the effect COVID-19 has had on social norms, perceived barriers to behavioural change, and on the value placed on international leisure travel, is an interesting area of study.

This thesis studied well-connected capital regions in two affluent countries, thus the results are context-dependent. Studying the long-distance travel patterns of the populations of less well-connected cities, rural areas or well-connected capitals in less affluent nations could reveal new insights.

As frugality shares many of the same functions as PEBs, such as saving water, electricity and heating, buying second-hand furniture and clothing, and repairing possessions rather than buying new ones, an interesting area of study would be to see whether compensatory green behaviours could also partly be a manifestation of the rebound effect. Controlling for identified predictors such as migration, cosmopolitan attitudes, household type, and income; do those who practice certain low-cost PEBs travel more by plane, due to monetary saving in daily life?

Overall, more research is needed on carbon footprints of individuals, compared to their stated PEBs, to shed light on the carbon mitigation potential of different PEB categories. With that in mind, it is important to assess the place of each behaviour in “sufficient lifestyles,” based on the concept of consumption corridors, where everyone can live a good life, but within the limits set by the planetary boundaries (Di Giulio & Fuchs, 2014; Fuchs et al., 2021).

4.5 Conclusion

Previous literature has critiqued the effectiveness of identifying drivers and barriers in relation to the attitude-behaviour-choice (ABC) framework, arguing that no significant societal transformation will come of it, and that changing to more PEBs is not effective enough (Shove, 2010). In addition, it has been doubted that consumers are even capable of significantly lowering their carbon emissions (Whitmarsh, Seyfang, & O'Neill, 2011), and some argue that the responsibility is unjustly placed on the individual with the ABC framework, as it is the government that forms the options and possibilities for individual behaviours (Shove, 2010). Although this thesis is on behavioural change, it is fully acknowledged that the responsibility for climate change mitigation does not solely lay on the individual. However, demand-side mitigation measures have also been recognized as crucial in the fight to limit climate change (Myles et al., 2018). It can be debated whether top-down or bottom-up approaches are more effective, but for societal changes to happen it can be argued that both are needed. Policy requires support from individuals to avoid push-back, and in democratic societies individuals place votes for governmental representatives. When norms shift towards PEBs, it is in turn more likely that government officials will reflect those environmental standards and bring about significant change. Those changes can range from small changes such as a revision of urban planning documents to significant ones, such as a shift towards a degrowth economy. A holistic societal shift towards a more environmentally sustainable world consists of multiple smaller shifts. In order to understand the cultures and social norms related to environmentally significant behaviours, and the context dependency of the drivers and barriers within them, research is imperative.

All in all, this research shows the importance of cultural and social norm factors as barriers to environmentally sustainable behaviour, beyond direct impacts of urban form or PEAs. While it seems relatively clear that the car-oriented culture in Reykjavík is a product of decades of private vehicle-focused planning, changing that culture requires more than a shift towards planning for better access to alternative transport modes. The culture lingers, which was illustrated by respondents' unwillingness to even try other modes, justified by time constraints, weather, and perceived low quality public transportation, even though participants who actively used alternative travel modes expressed little discontent. This demonstrates the indirect impacts of urban form, as cultures are molded through previous urban development. The same goes for international flights, with the dominant social norm around flying which dictates that flying is necessary for well-being; urban form may well affect cosmopolitan attitudes, which cluster centrally and in turn drive international travel emissions. The indirect effects of urban form can also be seen related to reduced car-ownership rates in the city center hindering domestic travel, which may then be compensated for with more international travel. In addition to enforcing strong environmental policies through top-down approaches, it therefore would seem practical to actively strive towards changing culture and norms. Facilitation of pro-environmental behaviour through urban planning and dissemination of information on the climate change impacts of behaviours are good policy tools, but alone are not sufficient to avoid catastrophic warming.

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Articles 1-5

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