Why do urbanites travel more than do others? A review of associations between urban form and long-distance leisure travel

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TOPICAL REVIEW

Why do urbanites travel more than do others? A review of associations between urban form and long-distance leisure travel

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Abstract

Negative relationships between urban density and greenhouse gas emissions from daily travel are well established in the literature. However, recent research suggests that higher urban density is associated with higher emissions from long-distance leisure travel, such as car weekend trips and international flights. This article presents the first systematic review of empirical evidence on these associations and discusses potential explanations. A two-step article selection process yielded 27 empirical articles, complemented by one article published during the review process. When international travel is included in the analysis, the results suggest that residents of the largest cities, and particularly those from centrally located and densely built areas, travel more to cover long distances than do others, after controlling for demographic and socioeconomic variables. When only domestic travel is included, residents of larger settlements and areas of higher density engage in less long-distance travel for leisure purposes than those living in smaller settlements and sparsely built areas. The results of the review are indicative and warrant more research. Generalization is currently limited because of the wide variety of travel behavior measures used, consideration of different travel modes and trip purposes, and geographic scope. There is a strong need for replication of the results using consistent methodology, using data from longer and more recent time spans, and expanding to more diverse geographical settings, especially outside Europe. The systematic review is followed by a narrative review of theoretical explanations of the associations. The most common explanations include: rebound effects, the compensation hypothesis, access to transport infrastructure, urban lifestyles, sociopsychological characteristics, and social networks. Socioeconomic variables are controlled in a majority of the reviewed studies, and business travel is excluded from the review, so the concentration of wealth and business in cities may explain the findings only to some extent. Nonetheless, there is not enough empirical evidence on the causal character of the associations and therefore further qualitative and multidisciplinary work is needed. Compact city and urban densification policies are not strongly challenged by current evidence, and most common policy recommendations point to including air travel into carbon taxing or quota schemes.

1. Background

Global anthropogenic greenhouse gas (GHG) emissions should be rapidly reduced to avoid major global warming according to the Intergovernmental Panel on Climate Change (IPCC) (2014). Transport has long been one of the largest GHG emission sources and the emissions from the sector have been increasing, despite numerous initiatives for cutting them (IPCC 2014). Traditionally, ground transport has drawn the focus, whereas air travel was thought to have only a minor overall impact (e.g. Sims *et al* 2014, Hill *et al* 2012, Berntsen and Fuglestvedt 2008). However, aviation is a rapidly growing sector (Hill *et al* 2012,

Sims *et al* 2014), and many recent studies suggest it is at least as important a source of climate forcing as passenger cars, particularly when accounting for the strong impact on radiative forcing of short-lived GHGs emitted by planes (Aamaas *et al* 2013, Reichert *et al* 2016, Aamaas and Peters 2017, Brand and Preston 2010). Services related to tourism, including transport, have been recently estimated as a source of 8% of global carbon emissions (Lenzen *et al* 2018).

Several recent studies have found positive associations between urban density or settlement size and long-distance travel behavior after controlling for demographic and socioeconomic variables (e.g. Holden and Norland 2005, Ottelin *et al* 2014, Reichert *et al* 2016). Some authors suggest that compact city and urban densification policies may have unintended effects, and that there is a tradeoff between car travel and air travel (e.g. Ottelin *et al* 2014). The evidence suggests that the 'gains' from reduced daily travel in dense urban structure are to a considerable extent offset by 'losses' from increased emissions from medium- and long-distance travel (Ottelin *et al* 2014, Reichert *et al* 2016). The few studies differentiating particularly the emissions attributable to urban form suggest that the effects are relatively strong (Reichert *et al* 2016). This is potentially due to association between long-distance travel and urban form, and to the very high proportion of long-distance mobility in total travel-related emissions. The proportion is especially high when calculations account for the high radiative forcing in the atmosphere of short-lived GHGs emitted by planes (Aamaas *et al* 2013, Reichert *et al* 2016, Aamaas and Peters 2017, Brand and Preston 2010). Potential causal links between urban form and long-distance travel may appear tenuous, but there is currently no plausible evidence to either accept or reject this possibility.

Transportation studies have predominantly focused on daily travel, and there is a plethora of individual studies and literature reviews available (Newman and Kenworthy 1989, Rickwood *et al* 2008, National Research Council 2009, Ewing and Cervero 2010, Næss 2012). Even though there are continuing debates over the specific character of the influence of urban form on daily travel behavior (e.g. Næss 2014, van Wee and Boarnet 2014), the empirical findings are relatively uniform, showing that distance to city center and urban density reduce daily travel distances and emissions, and thus support urban density as a key urban planning target.

At the same time, there have been no systematic reviews on associations between urban form and long-distance travel, despite a growing number of empirical studies and potential relevance for policy-making. The existing empirical studies have been conducted in diverse geographical settings with a diverse set of approaches, methods, and variables. Drawing conclusions from such a heterogeneous set of articles is challenging without a systematic review. Future research would also benefit from a review of the methodological differences.

Providing empirical evidence and plausible explanations of causal relationships between urban structure and long-distance travel would throw light on the unintended effects of urban densification policies and inform mitigation (Holden and Linnerud 2011). Nevertheless, empirical evidence and theoretical discussion on such relationships have been scarce and fragmented. Researchers have suggested multiple potential explanations for such associations, but rarely verified them empirically or clarified them conceptually.

The first aim of this review is therefore to provide a context-sensitive summary of empirical findings on associations between urban form and long-distance leisure travel behavior. This aim has been realized by answering the following three research questions:

RQ1. What are the associations between urban form and long-distance leisure travel behavior found in empirical studies?

RQ2. How do the associations differ between geographical and methodological settings of the empirical studies?

RQ3. To what extent does the increase in long-distance travel related to urban form offset the concurrent decrease in daily travel?

The second aim was to provide a review of methodological limitations of the empirical studies and provide guidance for future research. This aim is realized by answering the fourth research question:

RQ4. What are the most important methodological limitations of previous empirical studies?

The third aim was to further the theoretical discussion on the potentially causal links between urban form and long-distance travel. To realize this aim, we answered the fifth research question:

RQ5. What are the most common theoretical explanations of the associations between urban form and long-distance travel behavior formulated in previous empirical studies?

The five research questions are here answered with a systematic literature review. Furthermore, to realize the third aim, we provide a narrative review of the hypothetical explanations for relationships between urban form and settlement structure, on the one hand, and long-distance leisure travel on the other. We specifically focus on the four most common hypotheses given in the previous literature (i.e. rebound effect, access to transport infrastructure, the compensation hypothesis, and lifestyles and other socio-psychological characteristics) but also aim at expanding the theoretical basis for future research by discussing relevant concepts from multiple disciplines.

We close the article with suggestions for further research on the topic, more refined research directions,

and guidance on research design and methods. Furthermore, we discuss potential policy implications of the current evidence base.

2. Methods

We conducted a systematic search of articles presenting empirical results on associations between urban form and long-distance leisure travel. We understand urban form as all spatial structural characteristics of the built environment, including settlement size, population and housing density, as well as local and regional accessibility to transport infrastructure, employment, services, and green areas, related to the residential location of the studied population. To cover diverse definitions of long-distance travel used in the studies reviewed, we defined it broadly as all trips away from the settlement or urban region of residence. The review focuses on trips made for leisure purposes, including trips made to visit family or relatives.

We included articles that conform to the following criteria:

1. Empirically measure at least one aspect of long-distance travel behavior that influences its GHG emissions (e.g. participation in travel, trip frequency, mode choice, travel distance, energy use) or GHG emissions associated with this travel behavior,
2. analyze associations between urban form and at least one of the above aspects of long-distance travel behavior,
3. analyze the above relationships without restricting trip destinations to specific locations or areas smaller than one country.

We applied these criteria in a two-step selection process. First, we conducted a snowball selection, collecting the papers known by the authors, searching through their references and again the references of the new papers added to the collection, and so on. This selection method yielded 23 articles. Then we performed two queries, one in SCOPUS and one in Web of Science. The last search was performed on October 5, 2017. Only English-language articles in academic peer-reviewed journals and chapters in books published by academic publishers were included. The queries were not restricted by publication date.

The search string for the SCOPUS query was:

TITLE-ABS-KEY (‘urban form’ OR ‘urban structure’ OR ‘built environment’ OR ‘spatial data’ OR ‘urban planning’ OR ‘environmental factors’ OR ‘residential location’ OR ‘density’ OR ‘urbanity’ OR ‘compact city’ OR ‘land-use related factors’ OR ‘structure of the urban system’ OR ‘population density’ OR ‘urban’ OR ‘rural’ OR ‘household location’ OR ‘accessibility’ OR ‘private garden’ OR ‘inner-city’ OR ‘suburban’ OR ‘green areas’) AND TITLE-ABS-KEY (‘personal carbon footprint’ OR ‘GHG emissions’ OR ‘environmental impact’ OR ‘CO_2’ OR ‘carbon’ OR ‘greenhouse gases’ OR ‘greenhouse gas emissions’ OR ‘emissions distribution’ OR ‘climate impact’ OR ‘travel distance’ OR ‘travel mode’ OR ‘mode use’ OR ‘consumption of transport’ OR ‘amount of travel’ OR ‘trip distance’ OR ‘frequency of trips’ OR ‘frequency of flights’ OR ‘level of travel’ OR ‘participation in travel’) AND TITLE-ABS-KEY (‘long-distance travel’ OR ‘air travel’ OR ‘medium- and long-distance travel’ OR ‘medium-distance travel’ OR ‘holiday travel’ OR ‘leisure travel’ OR ‘international travel’ OR ‘long-distance trips’ OR ‘medium-distance trips’ OR ‘private travel’ OR ‘leisure trips’ OR ‘leisure mobility’ OR ‘leisure-time travel’ OR ‘travel by plane’ OR ‘international mobility’).

The search string for the Web of Science was identical in its logic and content. The queries provided 86 and 46 results, respectively. After scanning titles, reading abstracts, and then reading full texts of the selected articles to check against our selection criteria we retained 11 articles from the SCOPUS search and nine articles from the Web of Science search. Among these, eight and six articles, respectively, were already included in the snowball selection, and the three remaining from both databases were the same. We further complemented the list with one article published during the review process. The final list therefore consists of 27 articles.

We conducted a detailed review of the selected articles and compared them regarding study area and geographical scale, types of travel included, travel modes analyzed, measures of travel behavior or related emissions, urban form measures, methods of analysis, and consideration of sociopsychological factors. Form each article we collected specific results related to urban form, key conclusions, theoretical explanations, policy recommendations, suggestions for future research, and hypotheses for further research.

3. Results

This section includes results of the systematic review of empirical findings on associations between urban form and long-distance leisure travel behavior. To provide context- and method-sensitive conclusions, we analyzed the results across dimensions, as listed above. We used these dimensions to describe the articles in table 1, illustrate the reviewed studies on a chart (figure 1), and to structure result description and conclusions presented in the following sections.

3.1. Summary of findings

The section answers the first two empirical research questions. Table 1 provides an overview on the 27 articles included in the final review.

Figure 1 provides an illustration of the main findings and methodological differences of the reviewed articles. Particularly, it classifies the articles according

Table 1. Key attributes of reviewed studies.

No	Authors	Yr.	Country	Travel behavior variables	Travel modes	Travel geog. extent	Urban form aspects	Controlled variables	Analysis method	Study geog. extent
1	Frändberg and vilhelmson	2003	Sweden	Frequency, distance	Combined	Domestic, international	Urban-rural	SED, health	Bivariate, regression	One country
2	Høyer and Holden	2003	Norway	Distance, ecological footprint	Air, car	All	Density, housing type, distance to center	SED, Car	Bivariate, regression	Three cities
3	Holden and Norland	2005	Norway	Energy use, travel time	Air, Car	All	Density, mix, distance to center, private yard, housing type, PT access	SED, car, dwelling, SP	Bivariate, regression (linear)	Eight areas in one city
4	Næss	2006	Denmark	Distance, participation, frequency	Air, Combined	Doms-tic, international	Distance to center, density, PT Access	SED, Car, SP	Regression (linear, logistic, ordinal), qualitative	One city
5	Limtanakool, Dijst and Schwanen	2006	Netherlands, UK	Participation	Car, train	Domes-tic	Density	SED, car	Bivariate, regression (binary logit)	Two countries
6	Ornetzeder, Hertwich, Hubacek, Korytarova and Haas	2008	Austria	Emissions	Air, car	All	Car-free vs. regular settlement	None	Bivariate	Two areas in one city
7	Brand and Boardman	2008	UK	Distance, emissions	Air, car, bus, train, ferry	All	Settlement size, urban-rural	None	Bivariate	One region
8	Nicolas and David	2009	France	Distance, emissions	Air, car, bus, train	All	Settlement size, urban-rural	None	Bivariate	One country
9	Brand	2009	UK	Emissions	Air, car, train, combined	All	Settlement size, urban-rural, accessibility	SED, Car	Bivariate, regression (linear)	One region
10	Brand and Preston	2010	UK	Emissions	Air, car, bus, train, ferry	All	Settlement size, urban-rural, accessibility	SED	Regression (linear, stepwise)	One region

Table 1. *Continued.*

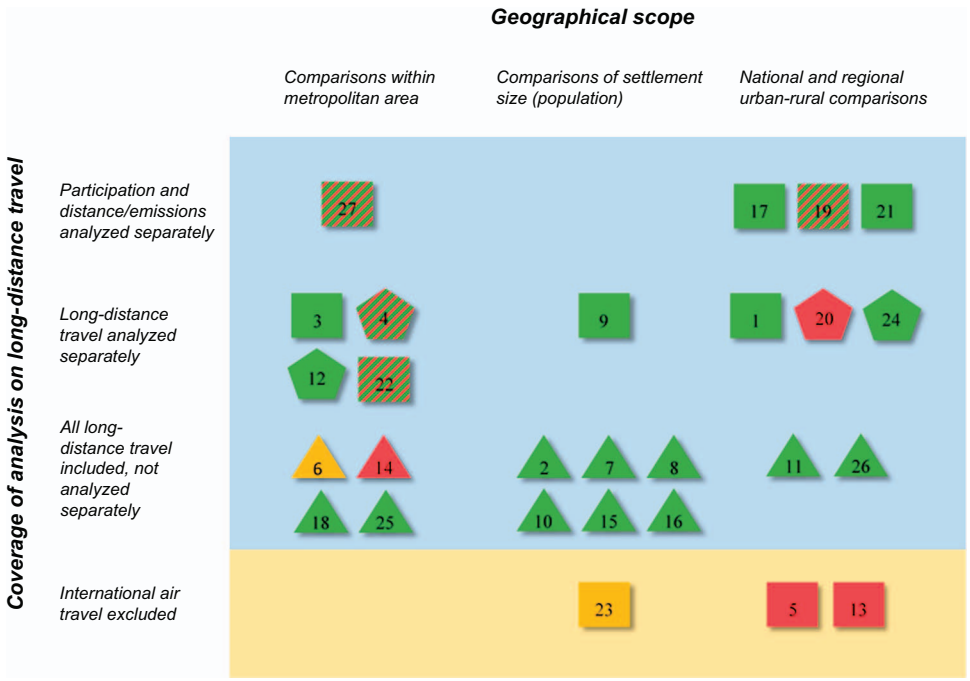
No	Authors	Yr.	Country	Travel behavior variables	Travel modes	Travel geog. extent	Urban form aspects	Controlled variables	Analysis method	Study geog. extent
11	Heinonen, Kyrö and Junnila	2011	Finland	Emissions	Air, car, bus, train, ferry	All	Urban—suburban	None	Bivariate	One city
12	Holden and Linnerud	2011	Norway	Energy use	Combined	All	Density, mix, private yard, distance to center	SED, Car, 2nd home, SP	Regression	Eight areas in one city
13	Dargay and Clark	2012	UK	Distance	Air, car, bus, train, combined	Domes-tic	Settlement size	SED, Car, Dwelling	Regression (WLS)	One country
14	Muñiz, Calatayud and Dobaño	2013	Spain	Ecological footprint	Combined	All	Density, distance to center, coastal	SED, SP	Regression	One city
15	Heinonen, Jalas, Juntunen, Ala-Mantila and Junnila	2013	Finland	Emissions	Air, car, PT, ferry	All	Settlement size, urban-rural	SED	Bivariate	One country
16	Heinonen, Jalas, Juntunen, Ala-Mantila and Junnila	2013	Finland	Emissions	Air, car, PT, ferry	All	Settlement size, urban-rural	None	Bivariate	One country
17	Holz-Rau, Scheiner and Sicks	2014	Germany	Distance	Combined	All	Settlement size, density, accessibility	SED	Regression (two-step: probit, OLS)	One country
18	Ottelin, Heinonen and Junnila	2014	Finland	Emissions	Air, car, PT, ferry	All	Density	None	Bivariate	One country
19	Reichert and Holz-Rau	2015	Germany	Participation, distance, mode	Air, Car, Train	All	Density, settlement size, PT access	SED, car	Regression (two-step: logit, OLS)	One country
20	Boucher	2016	USA	Emissions, participation, frequency	Air, Car	All	Density	SED, SP	Regression (OLS)	One country
21	Reichert, Holz-Rau and Scheiner	2016	Germany	Emissions, participation	Air, car, PT, combined	All	Density, settlement size, accessibility, PT Access	SED, Car	Regression (two-step: logit, OLS)	One country

Table 1. *Continued.*

No	Authors	Yr.	Country	Travel behavior variables	Travel modes	Travel geog. extent	Urban form aspects	Controlled variables	Analysis method	Study geog. extent
22	Næss	2016	Norway, Denmark	Distance, frequency	Air, Car	Regional, international	Distance to center, housing type	SED, 2nd home	Regression, Qualitative	One city
23	Arbués, Baños, Mayor and Suárez	2016	Spain	Mode	Car, train, bus	Domestic	Settlement size, density, PT access	SED, SP	Bivariate, regression (utility, logit)	One country
24	Bruderer Enzler	2017	Switzerland	Participation, emissions	Air	All	Density, airport access	SED, SP	Regression (hurdle: probit, OLS)	One country
25	Chen, Hadjikakou, Wiedmann and Shi	2017	Australia	Emissions	Car, PT, air	All	Urban- suburban	None	Bivariate	One city
26	Ottelin, Heinonen and Junnila	2017	Finland	Emissions	Combined	All	Urban-rural	SED	Regression	One country
27	Czepkiewicz, Ottelin, Ala-Mantila, Heinonen, Hasanzadeh and Kyttä	2018	Finland	Emissions, participation	Car, train, bus, plane, ferry, combined	Domestic, international	Urban- suburban / PT access, housing type, private yard	SED, car, workload	Bivariate, regression	One city

Abbreviations and terms used in the table:

- SED: Socioeconomic and demographic variables.
- Car: Variables related to car availability, car ownership, and driver licenses.
- SP: Sociopsychological variables such as environmental concern, travel-related attitudes, lifestyle preferences, political orientation, etc.



Green = the amount of travel (e.g. participation, trip number, distance, emissions, energy use) increase with increasing level of urbanity (e.g. density, increasing settlement size, and/or decreasing distance to city center)

Red = the amount of travel does not increase with increasing level of urbanity (the relationship is negative or statistically insignificant)

Striped green-red = separate analyses yield divergent results

Yellow = not applicable

Triangle = bivariate analysis on long-distance travel

Square = multivariate regression analysis controlling for socioeconomic and demographic (SED) variables

Diamond = multivariate regression analysis controlling for SED variables and socio-psychological variables

Figure 1. The findings of the reviewed articles on the association between urban structure and long-distance travel. Numbers refer to the list of articles in table 1.

to the geographical scope and the coverage of analysis on long-distance travel. It should be noted that the classification is not ordinal but descriptive. Table A1 in the appendix gives more details on the impact of urban form aspects on long-distance travel under various circumstances by presenting the regression coefficients from the reviewed studies that include regression analysis for long-distance travel.

The majority of the reviewed studies found positive associations between level of urbanity and long-distance travel. In figure 1, these studies have a green icon. Studies marked with a red icon did not find such a relationship. Many of the reviewed papers tested separately several urban structure variables, such as population density and distance to city center. In addition, some studies analyzed several outcome variables, such as number of trips and travel distance separately. Thus, some of the articles have a red-green striped icon. These studies found a positive relationship in some cases, but not in all (see table A1 in the appendix). The two studies marked with yellow icons do not address the question, but rather study mode choice (Arbués *et al* 2016) or a specific car-free settlement (Ornetzeder *et al* 2008).

The reviewed studies varied in their main method of analysis. In figure 1, studies that used only bivariate analysis to examine the relationship between urban structure and long-distance travel are marked with a triangle icon. Studies that used regression analysis and control at least for income are marked with a square icon. Most of these studies controlled other socioeconomic variables as well, but the selected variables varied from study to study. The studies that controlled sociopsychological variables are marked with a diamond icon.

The results varied depending on the geographical scope of trips. When only domestic or regional trips were included, association between urban density and amount of long-distance travel appeared negative. When international trips were included, the association between urban density and amount of long-distance travel was positive. In many studies longer holiday trips by plane were found to increase in relation to bigger and more densely built settlements, even when controlling for sociodemographic variables. In the following sections, we review the findings and the methods of the articles in more detail, dividing them according to geographic scope of comparison (metropolitan to

national), and geographical scope of travel (inclusion of domestic and international trips), and in the final section we summarize the amount of trade-off in emissions between low-density and high-density locations. It should be noted that the division into domestic and international trips is mostly applicable to Europe and other regions with relatively small countries, whereas in countries such as the United States, Brazil or China an additional level of division, such as state or province, might also be meaningful.

3.1.1. International trips included—regional urban form measures

Bivariate analyses show large regional differences in long-distance travel behavior between settlements of distinct size and density levels, with residents of the largest cities and metropolitan areas traveling the most (Brand and Boardman 2008, Nicolas and David 2009, Heinonen *et al* 2013a). After controlling for demographic, socioeconomic or sociopsychological variables, the effects of settlement size, agglomeration level, and urban density remain significant and positive in most studies (Frändberg and Vilhelmson 2003, Brand 2009, Brand and Preston 2010, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016, Bruderer Enzler 2017), with only one study from outside of Europe showing lack of association with population density (Boucher 2016).

A bivariate analysis by Nicolas and David (2009) showed a positive correlation between size of French agglomerations and emissions from long-distance travel of their residents, with disproportionately high emissions in the Paris region. A similar picture was drawn by Heinonen *et al* (2013a) who showed that air travel is more frequent in more urbanized areas of Finland (and especially in the Helsinki Metropolitan Area), while car use shows a reverse association with density. Brand and Boardman (2008) report that while the amount of car travel and its emissions are higher in rural areas than in large urban areas, the amount of air travel and its emissions show a reverse relationship. Total emissions from personal travel were also the highest among those living in large urban areas in the studied region of Oxfordshire (Brand and Boardman 2008).

After controlling for demographic, socioeconomic or sociopsychological variables, the effect of urban form remains significant but smaller in magnitude, and the interpretations are more nuanced. Brand (2009) and Brand and Preston (2010) find that emissions from air travel are smaller among residents of rural and medium urban areas than among residents of large urban areas. Frändberg and Vilhelmson (2003) similarly show that people living in large Swedish cities tend to take more international trips than people living in rural areas. The results of a German study (Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016) found that residents of large cities are more likely to participate in long-distance travel, travel further for leisure purposes, and cause higher emissions from long-distance travel than those who live in smaller settlements. The results also hold true for agglomeration level, with the size of the municipality held constant (Reichert *et al* 2016). Similarly, Bruderer Enzler (2017) concludes that residents of more densely populated areas in Switzerland fly more often and cause more greenhouse gas emissions from air travel than those who live in more sparsely populated areas. Conversely, Boucher (2016) found that census tract population density in the US is not significantly related to the air travel carbon footprint.

Besides travelled distances, there may be differences in rates of participation in certain types of travel. In the study of Reichert and Holz-Rau (2015), the higher amount of long-distance travel among residents of agglomerations and large cities was found to be largely due to the higher proportion of people who travel by train or airplane. According to Reichert and Holz-Rau (2015), the propensity to take train trips instead of car or airplane trips is partly explained by access to inter-urban train stations. The authors did not directly test the effect of airport accessibility, but it may be captured in their models by agglomeration level and municipality size. Bruderer Enzler (2017) did test airport accessibility directly and found that it positively influences the likelihood to fly for leisure purposes among Swiss residents, while controlling for population density.

The results presented above show differences in long-distance travel patterns on a national or regional scale, and analyze their association with settlement size, agglomeration level and regional density levels. However, urban planning policies often pertain to urban form characteristics on a metropolitan and local scale, such as neighborhood density, local access to services, or city compactness.

3.1.2. International trips included—local urban form measures

Both bivariate and multiple regression analyses suggest that people who live in densely built, pedestrian-friendly, and centrally located neighborhoods travel more over long-distances than those who live in more suburban locations. The results pertain specifically to air travel (Holden and Norland 2005, Næss 2006, Ornetzeder *et al* 2008, Holden and Linnerud 2011, Ottelin *et al* 2014, Næss 2016, Czepkiewicz *et al* 2018) and weekend trips (Næss 2006). On the other hand, the results regarding access to private or public green spaces are mixed (Holden and Norland 2005, Næss 2006, Holden and Linnerud 2011, Bruderer Enzler 2017).

Of the regression studies that control for socioeconomic and demographic variables, Holden and Norland (2005) and Holden and Linnerud (2011) have found that energy spent on long-distance leisure travel by plane increases with residential density but not with distance to city center or local centers in Oslo. Næss (2006) has found that local density of population and

workplaces at the neighborhood level in Copenhagen positively influences the likelihood of making weekend trips, distances traveled on weekend trips, and taking holiday trips by airplane. After controlling for local density, the distance to city center was associated with distances traveled on weekend trips and taking holiday trips by airplane, but not with the likelihood of making weekend trips (Næss 2006). After extending the study to three cities in Denmark and Norway, Næss (2016) concludes that inner city residents make private flights more frequently than others.

Czepkiewicz *et al* (2018) report that residents of central pedestrian zones of the Helsinki Metropolitan Area are more likely to travel internationally and take more flights abroad than those who live in more suburban and car-oriented locations, and that place of residence is only weakly related to participation in domestic travel. They also report that the amount of emissions from international travel is lower among those who live in one of the suburban zones than among those who live in the central pedestrian zone of the region. The residents of German neighborhoods with better walking access to groceries are more likely to participate in long-distance travel and associated emissions (Reichert *et al* 2016) and travel further during long-distance overnight trips for private purposes (Holz-Rau *et al* 2014). However, the associations were rather weak compared to municipality size or regional density (Reichert *et al* 2016).

The association between local urban density and leisure travel away from a city have been attributed to lack of opportunities for recreation and contact with nature close to home. There is currently only limited evidence for such a claim. Næss (2006) reports that the number of airplane trips for holidays was slightly *higher* among respondents with access to a green area above 10 ha close to home, after controlling for several sociodemographic and psychological variables. Using housing type as a proxy for access to a private garden, he concludes that it is not correlated with the number of leisure flights per year. Conversely, Holden and Norland (2005) and Holden and Linnerud (2011) found that access to a private garden is related to lower energy use for leisure travel by Oslo residents, both by car and plane, regardless of housing type or residential density level. Bruderer Enzler (2017) controlled in one model for 'seeing greenery from one's apartment' along with urban density, but found no significant relationship with participation in air travel.

In general, the literature reviewed indicates a positive association between a variety of urban density and agglomeration measures and long-distance leisure travel. Similar results can be found in studies conducted on various geographical scales: metropolitan, regional, and national. However, when international trips, and particularly flights, are not included in the analysis, the associations between urban form and long-distance travel show a strikingly different pattern.

3.1.3. Only domestic or regional trips included

Studies that did not include international trips and were conducted on a national scale suggest that amount of long-distance leisure travel *decreases* with higher population density (Limtanakool *et al* 2006a), and larger municipality size (Dargay and Clark 2012). The results about mode choice are mixed and inconclusive (Limtanakool *et al* 2006b, Arbués *et al* 2016).

The results reported by Limtanakool *et al* (2006a) suggest that residents of British lowest-density areas are more likely than others to participate in leisure travel by both private car and train. Similarly, Dargay and Clark (2012) report that residents of metropolitan areas in Great Britain (and especially London) travel the least in terms of distance, while those from rural areas travel the most. Limtanakool *et al* (2006a) show similar results for the Netherlands, but the significant differences between areas of different density pertain only to participation in train trips. None of the reviewed studies reported greenhouse gas emissions associated with domestic trips.

This review includes two studies on mode choice in domestic trips. Arbués *et al* (2016) report that trips originating from smaller settlements in Spain are more likely taken by train than by car compared to those originating from bigger cities, and that trips originating from non-metropolitan areas are more likely taken by bus than by car compared with trips originating from metropolitan areas. In a study by Limtanakool *et al* (2006b), higher urban density at the *destination* increased the likelihood of choosing train over car for longer distance trips.

All the studies on domestic travel that were reviewed applied multivariate regression models and controlled for income and other socioeconomic variables, as well as for car availability. The latter is typically correlated with urban density and settlement size, which further highlights the role of urban form. Interestingly, Dargay and Clark (2012) report that domestic long-distance travel is greater for individuals living in detached houses, even when income and settlement size was controlled for. Limtanakool *et al* (2006a) suggest that residents of less urbanized areas use leisure trips to reach services not offered by their own settlements but located in bigger cities. The differences between Great Britain and the Netherlands suggest that participation in domestic long-distance travel is further modified by the overall settlement structure in a country and the size of the country itself (Limtanakool *et al* 2006a). Mode choice is further modified by access to infrastructure, among other factors.

The small number of studies reviewed and the methodological differences between them do not allow us to draw definitive conclusions, but some patterns arise. Most importantly, when only domestic travel is analyzed, the amount of long-distance leisure travel appears to *decrease* with increasing settlement size and population density. The results on mode choice are mixed and more studies from different countries

are necessary to strengthen the evidence and provide explanations. For instance, urban-rural differences in amount of domestic travel might be higher in countries with strongly dominating capitals (such as Great Britain, France, or Finland), and smaller in more polycentric countries (such as the Netherlands or Germany), but current literature does not allow for such generalizations.

3.1.4. *Trade-offs between long-distance travel and local travel*

The extent to which 'gains' in daily travel due to dense and compact urban form can be offset by 'losses' in long-distance travel, depend on the internal structure of travel behavior and related emissions. Air travel causes significantly higher emissions per trip, and therefore the overall level of emissions from long-distance travel largely depend on levels of participation in and the frequency of airborne trips. The share of air travel in all transport-related emissions varies between geographical contexts. In a study by Ornetzeder *et al* (2008) air travel accounts for 64% of travel and energy emissions in a car-free settlement, a value markedly higher than that of reference settlement (43%) and the Austrian average (ca. 28%). Ottelin *et al* (2014) report that only in childless households in the dense pedestrian zone of Helsinki, and in non-motorized households in the whole country, emissions from air travel exceed those from other travel modes. In a study conducted in the US air travel consisted of 26% of all transport-related emissions (Boucher 2016). In China, average carbon emissions from long-distance travel are approximately twice as low as those resulting from daily commuting (Xu *et al* 2015). The figures largely depend on how emissions from aviation are calculated. For instance, Aamaas and Peters (2017) attribute 32% of emissions to air travel by Norwegians when only CO_2 is considered, and 51% when the 50 year climate impact of short-lived climate forcers is included. After using a similar method of calculating emissions from aviation, Czepkiewicz *et al* (2018) report that yearly emissions from international travel are mostly comprised of air travel and constitute a high share of total travel-related emissions caused by Helsinki metropolitan area young adults. The share varies with location, but the total amount is similar in city center and in suburbs: emissions from international travel amount to ca. 3400 out of 4800 kg CO_2eq per person (ca. 71%) in central pedestrian zones, and to ca. 2300 out of 4800 kg CO_2eq per person (ca. 49%) in suburban car-oriented zones.

In a study by Ornetzeder *et al* (2008), emissions from air travel in a car-free neighborhood were only slightly higher (by about 300–400 kg CO_2 per person) than in a reference neighborhood and were similar to the Austrian average, while emissions from car travel varied a great deal (by about 1600 kg CO_2 per person compared to the Austrian average). Heinonen *et al* (2013a) found that a decrease in car use is to some extent compensated by increased air travel. In Heinonen *et al* (2013b), only the middle-income segment in Finland was included, and the authors noticed an increasing air travel pattern towards the more urbanized areas, but not strong enough to override the gains from concurrent reduction in the greenhouse gases from private driving. Ottelin *et al* (2014) report that total travel-related emissions are similar between non-motorized and motorized households in middle income class in the Helsinki Metropolitan Area, but in other income groups motorized households still cause higher emissions. The result suggests the existence of a trade-off between car-ownership and air travel in the middle-income group. The same study reports an increase in total emissions with urban density in the most central areas of Helsinki due to air travel.

According to Holz-Rau *et al* (2014), increasing distances traveled on long-distance trips to a substantial extent offset the shorter distances traveled daily by residents of cities above 0.5 million inhabitants. In cities with 0.5–1 million inhabitants the offset is mostly due to leisure trips, while in the largest cities there is also a vital role played by business trips that are analyzed separately. Reichert *et al* (2016) provide evidence that the 'gains' from reduced local travel in cities (and their dense, mixed and/or central parts) are to a considerable extent offset by 'losses' from increased emissions from long-distance travel, particularly air travel. The effect of sizes that may be attributed to urban structural variables are relatively high: between 400 and 1300 kg CO_2eq per year. This is due to the potentially strong effect that geography has on long-distance travel, but also to the proportion of long-distance travel in total travel-related emissions. On the other hand, a study by Chen *et al* (2017) reports that in Sydney the area with the highest emissions per capita from private and public transport (including air travel) is in the densely populated city center, despite high emissions from private car use in outer-ring suburbs. They further report that annual transport-related emissions range from 3000 kg CO_2eq per person in middle-ring western suburbs to 9500 kg CO_2eq per person in the city center.

Some of the reviewed studies combine emissions or ecological footprints resulting from long-distance travel with those from daily travel and other types of consumption. Høyer and Holden (2003) report that, after including long-distance holiday and leisure travels by car and airplane, the ecological footprint increases with the distance between the house and the city center in Greater Oslo in Norway. Muñiz *et al* (2013) report that the overall ecological footprint (based on energy consumption form housing and mobility) decreases with urban density in the Barcelona region, but only up to a density of about 180 inhabitants per hectare, and then increases. Ottelin *et al* (2017) report that the overall carbon footprints of those possessing cars but using them a little are lower than of those not possessing cars, but increase rapidly along

with increased driving. They also report small differences in the overall carbon footprints across different urbanity zones.

3.2. Review of methods

This section answers the third research question on methodological limitations of previous empirical studies. At the highest level, two distinct types of papers can be distinguished: those concentrating only on transport, and those including other aspects besides travel. Then, there are various approaches to collect data and to calculate distances and emissions. Finally, a wide variety of analytical methods have been utilized. Below we consider these issues from the perspective of survey sources and samples, measurement of travel behavior, emissions, and urban form, and the statistical methods utilized.

3.2.1. Geographical context

The material reviewed is strongly biased towards developed countries, and particularly Europe. Only two studies were conducted outside of Europe: one study analyzed data from Australia (Chen *et al* 2017) and one from the US (Boucher 2016). The remaining studies were based in Finland (six), the UK (five), Norway (four), Germany (three), Spain (two), Denmark (two), Sweden (one), the Netherlands (one), Austria (one), France (one), and Switzerland (one). Only two articles presented results from more than one country (Limtanakool *et al* 2006a, Næss 2016). This disparity strongly limits comparability and generalizability of existing results and calls for reproduction and the expansion of the geographical scope of research on the topic.

3.2.2. Survey sources and samples

Several distinct types of data sources have been utilized, with three predominant types. Eleven studies employed self-designed surveys to collect the data, ten used third-party national transport surveys, and five used third-party household budget surveys. In addition, third-party environmental opinion studies were the source in two studies. Only two studies employed in-depth interviews to complement quantitative survey data. Usually, third-party data sources are representative for the nation in question in accordance with the descriptions given, but in a large share the representativeness is not described, particularly in the case of the researchers' own survey datasets. In addition, the representativeness might be compromised in third-party cases also when only a subset of the data is utilized, but the issue is seldom considered.

The studies reviewed cover a relatively long time span, which affects the outcomes as air travel has become the most rapidly growing field of transport (IATA 2014). Five studies are based on data from 1994–2000 (Frändberg and Vilhelmson 2003, Limtanakool *et al* 2006a, Ornetzeder *et al* 2008, Nicolas and David 2009, Høyer and Holden 2003), and sixteen on data from between 2000 and 2010. This means that in only four studies does the data extend to the current decade (Ottelin *et al* 2014, Ottelin *et al* 2017, Chen *et al* 2017, Czepkiewicz *et al* 2018) during which air travel activity has been higher than ever before. In two papers, the data year is not provided (Brand and Preston 2010, Muñiz *et al* 2013).

3.2.3. Travel behavior measurement

One troublesome issue with studying long-distance travel and the related environmental impacts is that it often does not take place on a regular basis, and particularly not on an everyday, weekly or even monthly basis. Most travel surveys are based on short time spans and thus cover long-distance trips insufficiently, bringing an inherently high uncertainty factor to the studies in expanding their data on an annual level (Ottelin *et al* 2014). Still, as shown above, these datasets are commonly used in the studies reviewed.

In one study, the time-span for long-distance trips was less than one week (Limtanakool *et al* 2006a) and in seven from two weeks up to a month (Dargay and Clark 2012, Ottelin *et al* 2014, Arbués *et al* 2016, Heinonen *et al* 2011, Heinonen *et al* 2013a, 2013b, Ottelin *et al* 2017). Frändberg and Vilhelmson (2003), Nicolas and David (2009), Holz-Rau *et al* (2014) Reichert and Holz-Rau (2015) and Reichert *et al* (2016) utilized data collected over a 2–3 month span, whereas in 11 studies the time span was 12 months (Høyer and Holden 2003, Næss 2006, 2016, Ornetzeder *et al* 2008, Brand and Boardman 2008, Brand and Preston 2010, Bruderer Enzler 2017, Czepkiewicz *et al* 2018). In the rest of the studies reviewed the data collection time spans are not explained.

Another troublesome aspect is that in different studies very different definitions of medium- or long-distance trips have been used. In some, a requirement is set that such a trip includes an overnight stay (Reichert *et al* 2016, Reichert and Holz-Rau 2015, Holz-Rau *et al* 2014), whereas Limtanakool *et al* (2006a) exclude trips with overnight stays. In addition, in many papers the definition of included trips is not described in detail. The studies are also inconsistent in treating different travel modes. In some, air travel is excluded (e.g. Limtanakool *et al* 2006a, Dargay and Clark 2012), while others only cover flights (e.g. Bruderer Enzler 2017). Many studies also do not differentiate between travel modes and report results for all or several modes combined (e.g. Frändberg and Vilhelmson 2003, Holden and Linnerud 2011, Holz-Rau *et al* 2014, Ottelin *et al* 2017).

The studies reviewed analyzed a wide variety of outcome variables (table 1), which further complicates summarizing the results. Among the variables, the most common were utilization of specific types of travel (Næss 2006, Limtanakool *et al* 2006a, Reichert and Holz-Rau 2015, Reichert *et al* 2016, Bruderer Enzler 2017), number of trips in a given time frame (Frändberg and Vilhelmson 2003, Næss 2006, 2016),

travelled distances (Frändberg and Vilhelmson 2003, Næss 2006, Nicolas and David 2009, Dargay and Clark 2012, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Næss 2016), mode choice (Arbués *et al* 2016), energy use (Holden and Norland 2005, Holden and Linnerud 2011), greenhouse gas emissions (Ornetzeder *et al* 2008, Nicolas and David 2009, Brand 2009, Brand and Preston 2010, Heinonen *et al* 2011, Heinonen *et al* 2013a, 2013b, Ottelin *et al* 2014, Boucher 2016, Reichert *et al* 2016, Chen *et al* 2017, Ottelin *et al* 2017, Czepkiewicz *et al* 2018) and ecological footprints (Høyer and Holden 2003, Muñiz *et al* 2013).

Apart from participation in trips, number of trips, and mode choice, all the outcome variables are highly sensitive to distance measurement. Nevertheless, the authors rarely describe how they measured the distances. Where explanation was given, the distances were usually estimated by respondents (Næss 2006, Limtanakool *et al* 2006a, Brand and Boardman 2008, Brand and Preston 2010, Holz-Rau *et al* 2014, Ottelin *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016). In two studies, the distances were estimated from broad categories provided by respondents (Boucher 2016, Bruderer Enzler 2017).

The issues with travel behavior measurement, together with the wide variation in the time-spans described above, lead to limited comparability and generalizability. Furthermore, the issues with distance measurements also add to uncertainty in the estimation of greenhouse gas emissions.

3.2.4. *Emission measurement*

Greenhouse gas emissions or climate impact have been measured in 15 articles. Variation in the methods of assessment is high, creating high variation in the results and policy suggestions. Four types of method differences can be distinguished: inclusion of direct and indirect emissions, the range of GHGs included in calculations, calculation methods, and input data.

In one study, only the direct (tail-pipe) GHG emissions are included (Ottelin *et al* 2014). Six studies include the full life cycle perspective, including the indirect emissions both from fuel production, fuel transport, and vehicle production (Heinonen *et al* 2013a, 2013b, Ornetzeder *et al* 2008, Ottelin *et al* 2017, Chen *et al* 2017, Czepkiewicz *et al* 2018), of which Czepkiewicz *et al* 2018. also include the transport infrastructure component. They use travel distances for the assessment, whereas in the five others, the main utilized input data is monetary expenditures, particularly purchases of fuels, trip tickets and vehicles. In these five, long-distance transport is also only one of the emission sources in consumption-based carbon footprint calculations.

In five studies, the short-term climate impact of aviation has been given special consideration, which leads to showing by far the highest impact for air travel. Of these, Brand and Preston (2010), Brand and Boardman (2008) and Brand (2009) use aviation impacts multipliers on top of GWP100 basis, and Reichert *et al* (2016) and Czepkiewicz *et al* (2018) calculate 20 year GWP, including short-lived climate forcers (SLCFs) and aircraft-induced cirrus clouds with coefficients taken from Aamaas *et al* (2013). Reichert *et al* (2016) also show how much such estimates differ compared to assessment that only includes CO_2 emissions. In all these studies, air travel reaches close to, or even above, a 50% share of the overall emissions from all personal travel.

In two studies, the ecological footprint is calculated with transport as one item (Muñiz *et al* 2013, Hoyer and Holden 2003), although in the latter energy and distances for transport are discussed separately. Finally, in three studies the emission assessment is not described, but only reference to an earlier study or dataset is given (Bruderer Enzler 2017, Nicolas and David 2009, Boucher 2016).

3.2.5. *Urban form measurement*

The articles reviewed used a variety of urban form measures, but the consistent use of some of the measures facilitated comparisons. Studies conducted on a regional or national scale commonly used municipality or agglomerated population size (Brand and Boardman 2008, Nicolas and David 2009, Brand 2009, Brand and Preston 2010, Dargay and Clark 2012, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016, Arbués *et al* 2016) and the situation of regions on a rural to urban to agglomeration spectrum (Frändberg and Vilhelmson 2003, Heinonen *et al* 2013a, 2013b, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016).

The most common measure for both national and metropolitan scales was local population density (Høyer and Holden 2003, Holden and Norland 2005, Næss 2006, Limtanakool *et al* 2006a, Brand and Preston 2010, Holden and Linnerud 2011, Muñiz *et al* 2013, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Boucher 2016, Reichert *et al* 2016, Arbués *et al* 2016, Bruderer Enzler 2017). The geographical scale of comparison affects the interpretation of such measures (e.g. the effect of within-city differences in neighborhood density might obfuscate a study conducted on a national scale). Some studies accounted for such effects, for instance by including an interaction term between municipality size and local density level in regression models (Reichert *et al* 2016).

Another common measure used on a metropolitan scale is distance to city center (Høyer and Holden 2003, Næss 2006, Holden and Linnerud 2011, Muñiz *et al* 2013, Næss 2016) and therefore urbanity categories from inner urban to suburban to rural (Chen *et al* 2017, Ottelin *et al* 2017). Some of the studies considered local access to services (Brand and Preston 2010, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016) and land use mix (Holden and Norland 2005, Holden and Linnerud 2011). Among the least commonly used measures

were workplace density (Næss 2006), floor area density (Ottelin *et al* 2014), distance to local center (Holden and Linnerud 2011, Næss 2016), and distance to green space (Næss 2016). Finally, some of the studies used dwelling characteristics, such as housing type, dwelling size, or access to private garden (Høyer and Holden 2003, Holden and Norland 2005, Holden and Linnerud 2011, Dargay and Clark 2012, Næss 2016). Somewhat rarely applied were potentially highly relevant measures of access to public transport (Næss 2006, Brand and Preston 2010, Reichert and Holz-Rau 2015, Reichert *et al* 2016, Arbués *et al* 2016) and airports (Bruderer Enzler 2017). Czepkiewicz *et al* (2018) used an urban zone classification that combines distance to city center, distance to local centers, population and job density, and access to public transport.

In general, the usage of urban form measures was largely consistent across the studies which allowed for comparisons. The calculation of measures was usually reported in enough detail, even though some studies did not report the spatial units in which the measures were calculated, which sometimes hindered interpretation.

3.2.6. *Regression analyses*

Around half of the studies reviewed used regression analysis to examine the relationships between urban structure and long-distance travel behavior. Although socioeconomic variables were controlled in a majority of these studies, there were some other methodological limitations in the regression models used. First, only three of the studies controlled for attitudinal variables (Næss 2006, Holden and Linnerud 2011, Bruderer Enzler 2017), whereas variation in travel-related and pro-environmental attitudes may explain part of the observed variation in long-distance travel. Second, there were some possible collinearity problems in many of the studies. For example, Næss (2012) suggested that car-ownership should not be included in the same model with urban structure variables because they are interdependent. In the studies reviewed, Brand and Preston (2010), Holden and Norland (2005), Holden and Linnerud (2011), Reichert *et al* (2016) and Reichert and Holz-Rau (2015) included car-ownership or car accessibility in the same model with urban variables. However, Brand and Preston (2010) tested for collinearity problems and used a stepwise regression analysis. Third, an issue that most of the studies acknowledged, was the low frequency of long-distance travel compared to daily travel. Even in surveys that covered twelve months, the non-participation rate was high. Regression analyses on travel distance and emissions caused by long-distance travel include only the people who travelled. However, the probability of taking a long-distance trip is equally important. Holz-Rau *et al* (2014), Reichert and Holz-Rau (2015), and Reichert *et al* (2016) solve the issue by using a two-step regression analysis: they analyzed separately participation in long-distance travel (logit or probit model) and quantity (distance or emissions) of long-distance travel.

The geographical range of the studies gives reason for some analysis as well. Within metropolitan areas, job and consumption opportunities, as well as access to airport infrastructures, are similar in various districts. Regional and national studies, on the other hand, describe the impacts of urbanization in general. When income is not controlled, clearly the highest amounts of long-distance travel and emissions are found in the largest agglomerations of population (Nicolas and David 2009, Brand and Preston 2010, Heinonen *et al* 2013a). In such a context, the role of income in explaining the amount of travel might be different than in studies that look at within-city differences, since one of the main reasons for urbanization and locating in cities is increasing job opportunities and income.

4. Theoretical explanations

Despite the methodological diversity and limited comparability of the studies, we were able to identify patterns of association between urban form and long-distance leisure travel. To inform policy-making regarding sustainable urban form, research must also strive to establish causal links and plausible explanations of such associations. It is sometimes claimed in the literature that urban policies aimed at densification may have unintended 'opposite effects' or 'rebound effects' (e.g. Holden and Linnerud 2011). Reichert *et al* (2016) claim that their *findings challenge the idea that compact urban development may help reduce CO_2 emissions once long-distance trips are considered.* An important question is whether long-distance travel behavior is an *effect* of these policies or a correlation without causation.

Existing research does not provide compelling evidence for causal links between urban form and long-distance travel. However, authors of the articles reviewed hypothesize about the nature of such associations, and explain them with various micro-level processes. The most common explanations and processes found in the articles were:

1. Rebound effects (Holden and Norland 2005, Næss 2006, 2016, Ottelin *et al* 2014)
2. Compensation or escape hypothesis (Holden and Norland 2005, Næss 2006, 2016, Muñiz *et al* 2013, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016)
3. Access to transport infrastructure (Brand and Boardman 2008, Brand and Preston 2010, Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016, Bruderer Enzler 2017)
4. Lifestyles and other sociopsychological characteristics (Frändberg and Vilhelmson 2003, Holden and Norland 2005, Næss 2006, 2016, Heinonen *et al*

2013a, 2013b, Ottelin *et al* 2014, Holz-Rau *et al* 2014, Reichert *et al* 2016, Boucher 2016)

5. Dispersion of social networks (Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016).

In addition, it is commonly suggested that the increasing income level with increasing level of urbanization explains the increasing long-distance travel. The impact of income and other socioeconomic and demographic variables is controlled in the majority of the studies reviewed and the following discussion focuses on possible explanations for the differences remaining after controlling for these variables. It should be also noted that analyses on business travel, and its relation to the concentration of businesses in urban areas have been excluded from the review, since the aim was to summarize the findings on leisure travel. However, the concentration of wealth and global business in cities may still contribute to differences in leisure travel patterns between areas with differing levels of urbanization, for instance through the influence on lifestyles and social networks. These issues are discussed in corresponding sections.

In the following sections we first broadly discuss the issue of causality between urban form and travel behavior, and then summarize and expand the theoretical discussions provided in the articles reviewed around the five themes above.

4.1. Causality and residential self-selection

Whether and to what extent the urban form can have a causal effect on human behavior has been discussed by many authors in the context of local travel (Handy *et al* 2005, Næss 2016), physical activity (McCormack and Shiell 2011), and health (Bauman *et al* 2002, Martin *et al* 2014). The literature also provides conceptual models which explain what the pathways of such causal influence might be (e.g. van Acker *et al* 2010). The association between urban form and local everyday behavior is probably more direct than that between urban form and long-distance travel, but both geographical contexts may possibly be discussed using similar concepts. The conceptual models usually differentiate between urban form characteristics, socioeconomic and demographic characteristics, and sociopsychological characteristics (van Acker *et al* 2010). When urban form is the main factor of interest, the other factors are treated as confounding, mediating or moderating.

A cross-cutting theme crucial for identifying the character of the associations is residential self-selection (e.g. van Wee 2009, Cao *et al* 2009, Næss 2014). This concept refers to the tendency of various groups of people to locate in distinct types of residential environments. Travel-related preferences may influence residential choices and thus confound regression models that predict travel behavior based on urban form variables (van Wee 2009). Others have argued that causal effects between urban form and local travel exist regardless of transport-related residential self-selection, and that existence of travel-related residential preferences is a sign of such causality (Næss (2014). The issue has also been discussed in the context of long-distance travel (e.g. Reichert *et al* 2016).

The self-selection effects may be divided into those directly and indirectly related to long-distance travel. The direct effect relates to a situation in which residential location is chosen based on how well it supports intended travel behavior, for instance how convenient the access to travel infrastructure is (see section 4.4). The role of such an effect in model predictions is debated, and some authors suggest that its confounding effect is limited (see Næss 2014). The indirect effect refers to residential choices that are not directly related to the behavior in question. For instance, people who locate in inner-city neighborhoods for the sake of walkability and access to services, might be culturally or psychologically inclined (e.g. through cosmopolitan attitudes) to travel abroad more than those who locate in suburbs (see section 4.5). Such sociopsychological characteristics should be controlled for, as they potentially modify the strength of the association between urban form and travel behavior. However, the relationship may also have a reciprocal character. For instance, diverse urban environments may help people build extensive social networks or gain skills that support travel (see sections 4.5 and 4.6).

4.2. Rebound effect

4.2.1. Consumption-based environmental assessments

Broadly defined, the rebound effect means the unintended consequences of energy saving or climate change mitigating actions that are caused by shifts in consumption (Lenzen and Dey 2002, Hertwich 2005, Druckman *et al* 2011). In relation to urban form, it usually refers to higher energy spending or greenhouse gas emissions among people who live in densely built and centrally located areas, for instance due to differences in lifestyles, consumption patterns, and travel behavior. For example, even when controlling for income, city center residents may cause higher indirect emissions through elevated consumption of goods and particularly services (Ala-Mantila *et al* 2014). Studies on consumption-based carbon footprints and energy requirements in the built environment have found that the total environmental pressure per capita is strikingly similar regardless of the residential location when income is controlled (Lenzen *et al* 2004, Ornetzeder *et al* 2008, Heinonen *et al* 2013b, Minx *et al* 2013, Wiedenhofer *et al* 2013, Ala-Mantila *et al* 2013, 2014, 2016, Ottelin *et al* 2015, 2017, 2018, Chen *et al* 2017), although the emissions caused by car use increase strongly with increasing distance to city center and decreasing urban density. Ottelin *et al* (2017) suggest that this is partly due to the rebound effect for reduced car-ownership and driving.

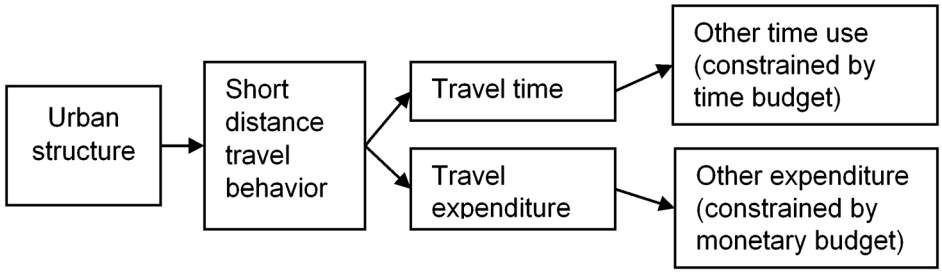


Figure 2. Causal chain from changing urban structure to rebound effects.

4.2.2. Rebound effect in travel behaviour studies

Studies focusing on the impacts of urban structure on travel behavior usually have a narrower view of the rebound effect that only considers expenditure on travelling. The idea of possible constant travel time and money budgets has been examined and discussed broadly (see e.g. review by Mokhtarian and Chen 2004). Mokhtarian and Chen (2004) conclude that travel time expenditure is strongly related to individual and household characteristics, and no universally stable travel expenditure exists. However, similar travel time and money budgets can be found within subpopulations and in certain areas. Vilhelmson (1990) suggested that the time and money people save from reduced short distance and daily travel may be used for long-distance leisure travel. Holden and Norland (2005) and Næss (2006) found some evidence supporting the idea. These early studies did not use the term 'rebound effect' but essentially discuss the same phenomenon. Holden and Linnerud (2011) discuss and review 'the unintended side effects' of sustainable transport policies, although including only the emissions caused by travel.

Ottelin *et al* (2014), Holz-Rau *et al* (2014), Reichert *et al* (2016) and Næss (2016) discuss the rebound effect directly. Ottelin *et al* (2014) focus on the monetary rebound effect and use the term similarly to consumption-based footprint studies (see above). Holz-Rau *et al* (2014) separate 'travel cost rebound' and 'urban form rebound'. They use 'travel cost rebound' to refer to the travel time and money rebound that allows people with less daily travel to invest more time and money on other travel. 'Urban form rebound', however, is a term similar to the compensation hypothesis (see the next section). Reichert *et al* (2016) use 'rebound effect' in the meaning that '*benefits in terms of the shorter trips made possible by dense, compact urban environments may be offset by* '*urban stress*' *that motivates people to make more frequent long* '*escape*' *trips*'. The varying terminology underlines the overlapping nature of the terms. Næss (2016) notes as well that the terminology between rebound effects and compensatory mechanisms is often blurred.

4.2.3. Causality of rebound effects

Monetary and time rebounds are causal effects that occur whenever the monetary and time travel budgets are interfered with. Figure 2 illustrates how the causal chain from changing urban structure leads to rebound effects. However, it is unclear how much of the detected differences in long-distance travel are due to the rebound effects. The time and money saved from reduced car ownership and use may be spent on many other purposes as well. Thus, rebound effects could explain the differences in the expenditure on long-distance trips, but so could other factors, and the current studies cannot separate these simultaneous effects. To establish stronger linkages, longitudinal and mix-method studies on rebound effects are called for. Nonetheless, the existence of rebound effects gives strong support for GHG assessments that include all consumption.

4.3. Compensation hypothesis

The *compensation* or *escape hypothesis* proposes that people who live in densely populated urban areas travel further or more frequently in their leisure time to compensate for deficiencies in their living environment, such as limited access to green or open spaces (Holden and Norland 2005, Hall and Page 2014), poor environmental quality and environmental stressors such as noise, crowding or hectic atmosphere (Strandell and Hall 2015), or more general dissatisfaction with the residential environment (Næss 2006). Strandell and Hall (2015) suggest that access to public green areas might be unrelated, but that compensation occurs when density increases and when there is no access to a private garden. They also propose that the need for compensation may depend on housing conditions, employment, and cultural and lifestyle contexts. Compensation is also closely related to the rebound effect (Reichert *et al* 2016, Næss 2016) and the two might be difficult to fully detach from one another. Some of the monetary and time savings from reduced car possession and use might indeed be spent on leisure travel away from the city, but not necessarily because of any deficiencies in the local environment. Conversely, only some of the *escape trips* might be associated with savings from daily travel.

If the compensation hypothesis is confirmed, it would prove that the urban form has a causal role in the long-distance travel behavior of the residents. However, among the studies reviewed, only some have identified factors potentially explained by compensation. A

few Nordic studies have found a positive relationship between local urban density and propensity to own and use summer cottages (Næss 2006, 2016, Strandell and Hall 2015). Holden and Norland (2005) and Holden and Linnerud (2011) report that in Oslo residents who have access to private gardens travel less by car and plane, regardless of whether they live in flats or single-family houses, but the association is also relatively strong for housing density. Næss (2006) in reporting higher medium- and long-distance trip frequency for city center residents in Copenhagen found qualitative evidence that some differences in weekend travel may be related to environmental quality but did not find such evidence in case of flight-based holidays. He concludes that compensation behavior has weaker influence on leisure travel patterns than monetary rebounds and cosmopolitan lifestyles (see next section). Finally, in the Netherlands, Sijtsma *et al* (2012) found a relationship between recreation opportunities in urban areas and holiday nights spent away.

In a more recent study Næss (2016) reports no evidence of compensatory behavior in Oslo, Stavanger and Copenhagen, contradictory to the above findings from these same locations. Maat and de Vries (2006) did not find associations between residential greenness, use of large parks and second home ownership in Arnhem the Netherlands. Muñiz *et al* (2013) in a study set in Barcelona rejected the compensation hypothesis but found that there was a maximum level of density beyond which the positive impact of density was reversed.

Overall, there seems to be relatively little empirical support for the compensation hypothesis. The results reported vary substantially and are even contradictory, suggesting that the study setting has a strong influence on the findings (see also Strandell and Hall (2015) for a more comprehensive overview). According to Næss (2006) the escape mechanisms need to be strong and occur frequently to challenge urban planning policies. In conclusion, the existing studies suggest that there is no uniform link between urban density and trips that compensate for deficiencies in the residential environment.

More focus on travel destinations and rationales behind leisure trips in relation to urban density is needed. Næss (2006) notes that he found evidence for escape trips among residents of dense urban area, but that the motivation was important only among a limited share of the respondents. It is possible that only people with need for contact with nature, enjoyment of nature, and preferences for natural leisure settings (e.g. Milfont and Duckitt 2010) engage in nature-related escape trips. Næss (2006) also notes that inner-city residents often travel to big cities abroad, and not necessarily to escape urban density or environmental stressors, for instance to engage in increasingly popular *city break* travel (e.g. Dunne *et al* 2010). Studies on travel destinations and activities taken at destinations could show whether and how often leisure trips are related to escaping urban environment, seeking contact with nature or other reasons. More generally, differentiation between *seeking* and *escaping* behavior (e.g. Richards 1999) could help to refine the concepts of escape or compensation travel when studying motivations behind trip frequency and destination choice.

Travel as compensation for what is lacking in everyday life may also relate to breaking daily routine, boredom or alienation, and such environmental factors as lack of daylight and harsh weather in winter or excessive summer heat. Furthermore, escape and seeking rest and relaxation are only some of the many motivations behind leisure travel, others being related, for example, to searching for social meaning or new experiences (Richards 1999). Finally, a reversed compensation behavior may explain the results of the studies that limit their geographical scope to domestic travel (e.g. Limtanakool *et al* 2006a, Dargay and Clark 2012). These studies suggest that small town and provincial residents travel more for leisure than residents of the largest metropolitan areas, probably in search of social or cultural stimuli unavailable in their home environment. Therefore, studies on destination choice could also further clarify the role of social and economic inter-city networks in motivating leisure mobility, besides verifying the compensation hypothesis.

Residential preferences may also come into play, as not everyone seeks access to green spaces or private yards (e.g. Kitamura *et al* 1997, Talen 2001), and compensation for missing qualities on weekend or holiday trips might be limited to people whose residential preferences are dissonant with their residential environment. The existing studies also do not fully differentiate between the effects of urban density *per se* and other environmental characteristics that are to some degree correlated with the density. Environmental stressors, such as noise, air pollution and crowding (e.g. Evans 2003) are somewhat related to urban density but also highly contextual. More direct measurement of the stressors could help to disentangle their effects from the effects of density itself. Furthermore, access to green spaces and outdoor recreation opportunities might be also provided in dense urban environments, and studies on the compensation hypothesis should carefully choose accessibility measures (Higgs *et al* 2012). Finally, it would be useful for policy-making to establish which density levels are associated with increase in leisure travel, following the study by Muñiz *et al* (2013) and studies that relate urban density to well-being (Bramley and Power 2009, Kyttä *et al* 2015).

4.4. Access to transport infrastructure

Several authors suggest that access to travel infrastructure may be another potential explanation of higher amounts of long-distance travel among urban dwellers (Brand and Boardman 2008, Brand and Preston 2010, Holz-Rau *et al* 2014, Reichert *et al* 2016, Bruderer Enzler 2017). Access to infrastructure may influence

which modes are chosen for travel for certain distances or trip purposes. For instance, Reichert and Holz-Rau (2015) found that the likelihood of selecting going by train instead of car or airplane is partly explained by access to train stations in Germany. The study did not directly test the effect of airport accessibility, but it could have been captured in their models by the agglomeration level and municipality size. Access to infrastructure may also affect price and easiness of travel. Bruderer Enzler (2017) tested airport accessibility directly and found that it positively influences likelihood to fly for leisure purposes among Swiss residents. However, such effect might be limited to differences between regions and settlements and may not explain within-city differences between areas of different density.

Access to infrastructure may also affect residential choices. As suggested by Reichert *et al* (2016), people with a preference for travel may tend to live closer to airports and important train stations. This direct kind of residential self-selection is also most likely to operate on regional to international geographical scales, i.e. people may consider access to infrastructure when choosing between moving to different cities rather than choosing between neighborhoods in one metropolitan area. Næss (2014) argues that preferences related to daily travel modes are not the most important criteria for residential preferences, and it is likely even less common in case of long-distance travel. While there might be people who choose place to live based on access to airports and train stations, the reverse effect is more likely, i.e. having good access to travel opportunities facilitate travel. There is a need for more studies that explore various aspects of residential choices in this context, for instance using qualitative methods such as residential biographies.

4.5. Lifestyles and other sociopsychological characteristics

The notion of lifestyle is proposed by some authors as a potential explanation for long-distance travel behavior (e.g. Næss 2006; 2016, Holden and Norland 2005, Frändberg and Vilhelmson 2003, Heinonen *et al* 2013a, 2013b, Reichert *et al* 2016). The concept of lifestyle is widely used in social sciences and the theory behind it is extensive and heterogeneous. In sociology, the notion of lifestyles has been used to describe observable patterns of behaviors that express someone's position in social space (e.g. Bourdieu 1984). More recently, it has been used to describe the motivations and orientations that underlie behaviors, such as travel patterns (van Acker *et al* 2010). Lifestyle orientations may be divided into fields, such as family, work, leisure, housing or consumption, and as such they inform choices related to residential location, car ownership or leisure travel patterns (Salomon and Ben-Akiva 1983). Relevant for leisure travel is the related concept of *mobility style* as a specific aspect of lifestyle that manifests itself in travel behaviors (Lanzendorf 2002, Ohnmacht *et al* 2009, Barr and Prillwitz 2012). Lifestyles and mobility styles are thought to be influenced by demographic and socioeconomic characteristics of individuals, but with the increasing individualization and pluralization of societies, the role of sociopsychological characteristics is thought to be more influential (Ohnmacht *et al* 2009). In the literature reviewed, lifestyles are usually considered a confounding factor, closely related to residential self-selection, whose influence diminishes the causal role of urban form on travel behavior (e.g. Næss 2006, Holz-Rau *et al* 2014). However, there is also a potentially reciprocal relationship between urban form and lifestyles. In the following sections, we discuss the role of demographic and socioeconomic characteristics on both residential location and long-distance travel, and then move to various sociopsychological and cultural aspects of urban lifestyles potentially relevant to the topic.

4.5.1. *Demographic and socioeconomic characteristics*

Sociodemographic and economic characteristics of individuals and households, such as age, household composition, occupation, income, and wealth, have been identified as important predictors of long-distance travel behavior (Holz-Rau *et al* 2014, Reichert *et al* 2016). The spatial distribution of residents differing in these characteristics is related to urban form, and thus should be controlled in the models used. Income level often differs between urban and rural areas, and between cities of distinct size, mostly due to better education, job and business opportunities. Differences in education opportunities also affect average education levels and demography (e.g. proportion of young adults), which also are important predictors of travel behavior (Reichert *et al* 2016). Concentration of wealth and global business in large cities further contribute to leisure travel through influences on lifestyle and social networks.

Spatial differences in socioeconomic and demographic characteristics are also observed within urban regions due to residential sorting. It is usually related to demographic changes in one's life course (e.g. moving out from smaller living quarters to a bigger apartment or house after having children), but relationship with education and wealth varies between regions. In many Nordic cities, e.g. Copenhagen, Helsinki, and Oslo, young and well-educated people tend to live close to the city center (Næss 2014). In other places, for instance in the US or China, the young and educated still tend to live further away from the centers (e.g. Ehrenhalt 2013, Næss 2014). The magnitude and direction of residential sorting is related to large-scale processes such as the shift from industrial to post-industrial modes of production and related trends of suburbanization and reurbanization. It is also related to psychological and cultural factors, such as attitudes towards urban lifestyles (Ehrenhalt 2013). The main takeaway is that socioeconomic and demographic factors should be controlled in regression models, as they were in the

majority of the studies reviewed for this article. However, researchers should bear in mind that relationships between these factors and urban living vary across geographical context, when interpreting descriptive and simulation studies. For instance, in regions where affluent people inhabit suburban areas, the travel-related or overall household emissions might appear to increase with decreasing urban density (e.g. Jones and Kammen 2014).

4.5.2. Urban lifestyles

According to the articles reviewed, certain lifestyle orientations and preferences, described as *urban lifestyles*, might be best expressed in cities, and particularly in dense and centrally located neighborhoods (Holz-Rau *et al* 2014). Authors have also suggested frequent long-distance trips, mostly by plane, to be an integral part of such urban lifestyles (Holden and Linnerud 2011, Holz-Rau *et al* 2014) and cosmopolitan orientation (Holden and Norland 2005, Næss 2006). Unable to find compelling evidence for rebound effects and the compensation hypothesis, Næss (2006) suggests that the higher number of flights among central Copenhagen residents is due to urban-cosmopolitan lifestyles. Summarizing Danish and Norwegian studies, Holden (2007) concludes that there is some support for the urban-cosmopolitan lifestyle explanation, as the associations between urban density and long-distance travel were found only in the larger cities. If this explanation holds true, it would undermine a causal character of associations between urban density and long-distance travel. However, this explanation is still speculative, and more qualitative or mixed-methods studies have been suggested to unravel this association (e.g. Næss 2006, Holden 2007, Holden and Linnerud 2011).

Clarification of what is understood by urban and cosmopolitan lifestyles would be useful for such research. According to Næss (2006), the urban-cosmopolitan lifestyle is characterized by both propensity for flights and preference for participation in urban leisure activities such as coffee shops, restaurants, and cultural events, predominantly in densely built centrally located neighborhoods. Such lifestyles are contrasted with the suburban patterns of behavior and consumption: single-family houses with private yards, car-oriented mobility, consumption in shopping malls, and family-orientation (e.g. Zukin 1998). Some studies provide evidence that the more urbanized area of residence, the less the residents spend time at home, and the more they consume leisure services (Heinonen *et al* 2013a).

The increase in popularity of urban living has been associated with the development from industrial to post-industrial modes of production in cities in the second half of the 20th century. Blue-collar workers previously dominating in the inner-city neighborhoods were increasingly replaced by people employed in the growing service-based economy. Such *gentrification* processes have been explained by both economic and cultural factors (Ley 1996, Zukin 1998). Densely built and centrally located neighborhoods have not only seen an increase in an affluent and well-educated population, but also have increasingly come to be seen as livable places (Ehrenhalt 2013). Recently, this *back-to-the-city* movement has been attributed to the Millennial generation, whose members often locate in walkable neighborhoods and choose a car-free lifestyle (Brown and Vergragt 2016). Research shows that walkable urban environments promote non-motorized travel (Ewing and Cervero 2010), provide benefits for physical activity (Sallis *et al* 2016) and social well-being (Appleyard 1981, Montgomery 2013). As such they have been promoted as beneficial for global sustainability and individual well-being and have become an important part of urban planning policies (Talen and Koschinsky 2013).

Urban lifestyles are usually associated with wealthy, educated and skilled professionals, and more often with single and childless households than with families (Zukin 1998, Næss 2006, 2016). These characteristics also correlate with increased frequency of flights, but even if these variables are controlled, some part of the variance remains explained by urban form. The remaining question is whether this influence is due to some relationship between urban lifestyle and cosmopolitan attitudes or willingness to travel (Holden and Norland 2005, Næss 2006, Holden and Linnerud 2011, Holz-Rau *et al* 2014) or does urban form play a role in promoting such attitudes and lifestyles.

4.5.3. Cosmopolitan lifestyles

In the meaning most relevant to the article, cosmopolitanism has been described as a set of attitudes, skills, and practices characterized by openness to, and desire for, otherness and cultural diversity (Young *et al* 2006). Throughout history, cosmopolitanism has been associated with urbanity, and cities have attracted cosmopolitan-minded people by virtue of their diversity and opportunities for contact with others (Kubicki 2016).

In a more narrow sense, researchers have attributed proliferation of cosmopolitan attitudes to formation of a *transnational elite*: highly educated and highly skilled professionals, employed in globalized industries, who have high cultural and economic capital (Rofe 2003, Bridge 2007). The social group has been related to globalization processes and the emergence of the well-connected network of *global cities* exemplified by New York City, London or Tokyo (Sassen 2005). The group members are thought to be multicultural, hypermobile, have extensive dispersed social networks, an extensive residential biography (i.e. have lived in many countries), and not necessarily attached to any specific place or a nation (Waldron 2000). This process is suggested as inherently linked to gentrification and the transnational elite as synonymous with a *global gentrifying class* (Bridge 2007), but empirical research shows that the groups overlap only somewhat

and are hardly synonymous (Rofe 2003). Cosmopolitanism and associated levels of leisure mobility appear to be very common only among those in the largest metropolitan areas, and those with the highest economic capital, but other urbanites may not share their lifestyle (Bridge 2007). Therefore, only some of the variation in leisure travel behaviors associated with urban density appears to be due to the hypermobile transnational elite. This kind of urban-cosmopolitan connection also seems limited to the largest cities, as suggested by Holden (2007). It might also apply only to the most mobile, regularly flying minority, identified for instance by Brand and Preston (2010).

4.5.4. *Symbolic consumption and class culture*

Urban lifestyle and long-distance travel may also be related on a much wider scale than only through the transnational elites. According to Bourdieusian theory, lifestyle choices result from an individual's *habitus* and form an unconsciously reproduced pattern of practices associated with social classes or groups (Bourdieu 1984, Grenfell 2014). In this view, the consumption practices do not necessary influence each other, but coincide in some social groups, e.g. among relatively affluent and educated members of the middle class, and are socially reproduced among their members. For instance, taking one or two international holiday trips, supplemented by occasional city breaks, and weekend trips to a summer house, might have become a social norm among middle class young adults who also happen to reside in walkable and centrally-located neighborhoods, without them having strong cosmopolitan attitudes or extensive international connections. According to Boucher (2016), the relative stability of such class cultures creates a *lifestyle lock-in* among affluent people, which might explain the lack of associations between environmental concern and long-distance travel behavior.

In this context, long-distance leisure travel is seen as a form of *symbolic consumption* (Richards 1999), used to construct one's social identity and differentiate from others. Frequent international travel might thus be a sign of social status, and belonging or aspiring to a certain social group such as urban middle class or the cosmopolitan elite. Urban environments then provide venues for displaying of the cultural capital acquired through travel and other forms of symbolic consumption to a larger extent than do rural or suburban environments (Rofe 2003, Zukin 1998, Kubicki 2016). There might be thus a correlation between symbolic consumption in urban environments and in long-distance leisure travel, which may partially explain why urban lifestyles and long-distance travel are tangled together, as suggested by Næss (2006) and Holz-Rau *et al* (2014). In this perspective, social class identities and social norms related to symbolic consumption should be treated as potential confounding factor and considered in future studies.

There are also potential feedback loops between urban environments, cosmopolitan lifestyles, and patterns of consumption. Densely built neighborhoods with diverse functions allow mixing and mingling with various people and provide more opportunities for contact, and thus might be attractive to the cosmopolitan-minded people (e.g. Jacobs 1961). Such places may also serve a conduit towards the cosmopolitan lifestyle for other people, e.g. through provision of restaurants with exotic cuisine, coffee shops, or art galleries (Rofe 2003). Opportunities associated with neighborhood density and walkability may reinforce the patterns of individualistic and symbolic consumption (Błaszczyk 2015). If these consumption patterns include travel, such urban environments may indirectly promote long-distance trips. Moreover, the influence of urban environments on travel may be of a cultural character. Large cities are places where *symbolic economy* develops, and elements of culture expressed in urban spaces, such as art, food, fashion, music, or tourism, are both its product and content (Zukin 1998). The producers of symbolic culture (i.e. the urban *creative class*, Florida (2002)) may project their desires and lifestyles to the consumers, thus motivating them to follow a similar pattern of consumption and travel. These are some of the ways in which compact cities may facilitate and foster formation of a tangled urban-cosmopolitan lifestyle as suggested by Holden and Linnerud (2011). However, the feedback mechanisms, even if conceptually compelling, might be difficult to empirically grasp in future studies.

4.5.5. *Personalities*

Evidence suggests that pro-environmental attitudes are largely inconsistent with long-distance leisure travel behavior (Holden 2007, Barr *et al* 2010, Davison *et al* 2014, Alcock *et al* 2017). Holden and Linnerud (2011) have suggested that this inconsistency may be attributed to attitudes and values that underlie both environmental awareness and preference for travel but are not included in regression models. Besides lifestyle orientations and social norms, such underlying factors may be related to personality traits.

Researchers have found a positive association between pro-environmental attitudes and values, and three of the 'Big Five' personality traits: *openness to experience*, *agreeableness*, and *conscientiousness* (Hirsh 2010, Nisbet *et al* 2009, Milfont and Sibley 2012). There is also a possibility that similar traits affect residential preferences. Jokela *et al* (2015) found that personality types cluster spatially in London: people with high *openness to experience* and *extraversion* are more likely to live in densely built neighborhoods, whereas people who score highly on *agreeableness* and *conscientiousness* are more likely to live in sparsely built areas. Indeed, openness and creativity are viewed by many as inherently urbane characteristics (Jacobs 1961, Florida 2002, Kubicki 2016).

Personality may also be related to long-distance leisure travel. For instance, people with high *openness to experience* might travel more than others, and

engage in specific types of travel more often, e.g. choose more exotic destinations (e.g. Richards 1999). Conversely, people who score high on conscientiousness and agreeableness are usually more family-oriented and may engage in trips related to family time, rest and relaxation. Currently, there is little empirical evidence for interrelationships between personality traits, long-distance travel and residential choices, and these should be explored in future studies.

4.6. Dispersion of social networks

The authors of the articles reviewed have suggested that urban residents travel more for long distances because they have more geographically dispersed social networks than other people (Holz-Rau *et al* 2014, Reichert and Holz-Rau 2015, Reichert *et al* 2016). Friends and families have become more geographically dispersed in recent decades, and social networks of urban populations tend to be more dispersed than those of rural populations (Reichert *et al* 2016). Higher education contributes to dispersion of social networks, especially if this includes studying abroad or participation in exchanges (Ohnmacht *et al* 2009). Many long-distance trips are taken to maintain social contacts (Reichert *et al* 2016). Spatial dispersion of social networks may to some extent reflect large-scale economic links of major cities (Holz-Rau *et al* 2014) and has been attributed to the formation of transnational identities in global cities (Sassen 2005). Some of the urban-rural difference in private travel may also be attributed to the higher share of immigrants, who are not necessarily wealthy, but travel to maintain contacts with families and relatives back home.

5. Conclusions and outlook

5.1. General conclusions

In general, the evidence on associations between urban form and long-distance leisure travel is indicative enough to motivate further research, but not definitive enough to inform policy. There have been too few comparable studies conducted to warrant broader generalizations. Nevertheless, we were able to draw the following conclusions.

RQ1. What are the associations between urban form and long-distance leisure travel behavior found in empirical studies?

Both bivariate and multiple regression analyses suggest that people who live in densely built, pedestrian-friendly, and centrally located neighborhoods travel more to cover long distances than those who live in more suburban locations. The results pertain specifically to air travel, and to a lesser extent to weekend trips. Similar patterns arose from studies that differentiate between urban and rural areas, and between settlements of different size and agglomeration level. Access to green spaces was not found to be a significant factor in the studies reviewed.

RQ2. How do the associations differ between geographical and methodological settings of the empirical studies?

The results varied strongly with changes in the geographical extent of trips considered in the analyses. When only domestic or regional trips were included, association between urban density and amount of long-distance travel appeared *negative*. When international trips were included, the association between urban density and amount of long-distance travel appeared *positive*. Differences in geographical extent of residential location have a smaller impact on the results: the associations were similar, whether the studies were conducted on a metropolitan, regional and national scale.

RQ3. To what extent does the increase in long-distance travel relate to urban form offset the concurrent decrease in daily travel?

The results are mixed. Increasing long-distance travel offsets somewhat the gains from reduced car use, but the magnitude varies from study to study. The amount of the trade-off in emissions between different types of travel also largely depends on how emissions from aviation are calculated.

RQ4. What are the most important methodological limitations of previous empirical studies?

There is a wide dispersion in the calculation methods, data sources, time spans, and scopes, which hinders comparability and generalizability of the results. Studies are not consistent in reporting and aggregating results pertaining to different travel modes, trip purposes, and geographical extent. Measurement accuracy and completeness are compromised by survey designs, specifically short recall times, relying on distance estimations by respondents, and not collecting data about travel destinations. Finally, most of the studies either do not include emissions at all, include only direct emissions, or calculate them as if they were all emitted on the ground level, albeit there is a relatively strong consensus that this method leads to a significant underestimation of the climate impact of aviation. While most of the studies control for socioeconomic and demographic variables, sociopsychological variables are often not controlled. Moreover, there is a dearth of mixed-methods or qualitative studies that would potentially explain the mechanisms behind the associations found in quantitative research. Empirical evidence is mostly limited to the European context and both replication and geographical expansion of research is necessary.

RQ5. What are the most common theoretical explanations of the associations between urban form and

long-distance travel behavior, formulated in previous empirical studies?

The most common explanations of the associations between urban form and long-distance travel behavior found in the review include: rebound effects, the compensation or escape hypothesis, access to transport infrastructure, lifestyles and other sociopsychological characteristics, and dispersion of social networks. However, there is currently not enough evidence to decisively support any of these explanations. There is indication that monetary savings from reduced car ownership and use might lead to more air travel, but the results are inconsistent, and it is unclear how prevalent this effect is and under which conditions it occurs. The results on the compensation hypothesis are similarly mixed and inconclusive. Residential self-selection issues and connection between urban and cosmopolitan lifestyles have been suggested as alternative explanation, but these have not been controlled in existing studies, and are rarely elaborated conceptually.

5.2. Future research directions

Further research should continue collecting evidence for associations between urban form and long-distance travel behavior with elaborated methods and various geographical settings. Such research would benefit from:

1. *Conducting more studies*, both replicating the results in similar geographic settings (Nordic and other European countries), and expanding research to other geographical regions, particularly those with high consumption levels but different settlement structures (such as the US, Canada, Australia or Japan) and growing levels of consumption and mobility (such as South-East Asia, the Middle East, Latin America, and Central and Eastern Europe). Future research should use more recent datasets, both third-party large-scale surveys, and custom surveys designed specifically to address this research question.
2. *Improving comparability of the results* by using a more consistent and granular measurement of travel behavior, i.e. calculating, analyzing, and reporting multiple variables, such as participation in travel, trip numbers, and distances travelled. The studies should differentiate between travel modes, trip purposes and geographic range. Comparability would be further improved with using a consistent set of urban form measures, supplemented with measures specific to a research question (e.g. access to transport infrastructure, access to green areas, dwelling type, access to private yard).
3. *Improving measurement accuracy* by using longer recall time frames and measuring distances without relying on estimation by respondent. Future studies should better describe methods and materials used, and assess uncertainties, as this was missing from many of the reviewed studies.
4. *Incorporating a high-quality measurement of long-distance travel to wide-range, representative surveys* on mobility, household spending, and general-purpose censuses and micro-censuses.

Importantly, future research should focus on identifying the character of the associations (i.e. whether there is causality or not), explaining the associations using concepts and theories from various disciplines, and providing evidence to support or reject these theories. Such research would benefit from following methodological improvements:

1. *Including in regression models a wider set of sociopsychological variables*, such as travel- and leisure-related attitudes, pro-environmental attitudes, lifestyle orientations, residential preferences, social norms, and personality traits.
2. *Using more complex modeling methods* such as path analysis and structural equation models. Such models should consider multiple interrelationships and confounding, mediating and moderating effects of sociopsychological, socioeconomic, demographic, urban structural and lifestyle-related variables.
3. *More consideration should be given to such themes as* residential self-selection, interrelations between leisure travel-related attitudes (e.g. enjoyment of nature) and residential preferences (e.g. importance of access to private and public green spaces), interrelationships between home and car ownership, income levels, household structure, and urban form, as well as studying further how pro-environmental attitudes affect long-distance travel and particularly if the attitudes are reflected differently in travel behavior in different types of living environments.
4. *Supplementing quantitative studies with qualitative research*, using mixed-methods research design, in-depth interviews, or focus groups. The qualitative research could focus, for instance, on motivations behind undertaking long-distance leisure trips, choosing trip destinations and connecting these motivations with characteristics of urban environment, social and cultural norms, and leisure activities in everyday life. Qualitative studies could also throw light on the expected and experienced influence that leisure travel and urban environment have on social and psychological well-being of individuals.
5. *Conducting longitudinal surveys or biographical studies*, that would reveal how long-distance leisure travel behavior changes in time and with events such as changes of residential location or dwelling characteristics, purchases of cars or apartments, or changes in household structure (e.g. having children, moving in with a partner).

6. *Systematic testing of theories that explain the associations and mechanisms behind them*, following the themes identified in the review. *Rebound effects* could be studied for instance by conducting quantitative studies that consider income and wealth levels, car and home ownership, and more detailed data on spending, and supplementing them with qualitative inquiries into motivations behind spending surplus income on leisure long-distance travel. Verifying *the compensation hypothesis*, could be done with quantitative studies that consider objective and subjective measures of environmental quality (e.g. annoyance with environmental stressors, satisfaction with residential environment, access to green spaces), character of trip destinations, and qualitative inquiries into motivations behind destination choices and trip frequencies (e.g. whether these motivations are related to environmental quality in residential location). The role of *access to transport infrastructure*, can be verified by conducting quantitative studies in multiple locations that have varying levels of access to airports and bus and train stations, varying connectivity of the airports and stations (e.g. number of connections), and varying price levels in relation to income. The relevance of *urban-cosmopolitan lifestyles*, could be verified by conducting quantitative studies that include a range of sociopsychological variables that measure attitudes and preferences related to lifestyle (e.g. leisure long-distance travel, residential preferences, everyday leisure activities) along with more general attitudes towards diversity and novelty. These could be supplemented by qualitative inquiries into cultural and social norms related to travel and urban lifestyle among people who belong to various social classes and inhabit various urban areas. *Dispersion of social networks* could be incorporated into quantitative studies by inclusion of variables that describe spatial range, quantity and quality of social connections. The role of long-distance travel in building social networks and the role of social networks in motivating leisure travel could also be a focus of qualitative studies.
7. *Developing conceptual models and clarifying terms and definitions.* Terms such as compensation, compensatory travel, rebound effect, urban lifestyles, and cosmopolitan lifestyles are used inconsistently in the literature and authors should pay more attention to defining the terms and developing conceptual models.
8. *Theoretical work should be grounded in multiple disciplines*, such as transport and tourism geography, social psychology, ecological economy, urban studies, environmental psychology, and psychological well-being.

Improvements in quantification are also called for. Estimation of greenhouse gas emissions should account for both direct and indirect emissions and impacts of short-term climate forcers associated with aviation. Emissions from long-distance travel should be comparable with and reported along the climate impacts from other sources, such as daily travel and other types of consumption. Particularly, researchers should analyze how much of the reduced emissions in daily travel due to urban density and compactness are offset by increased emissions in long-distance travel. Comparisons with climate impacts of other consumption would particularly enable air travel to be assigned the correct weight in policy-making information.

5.3. Policy considerations

There is currently not enough evidence to seriously challenge the dominating compact city and densification policies on the premise that they cause higher climate impacts from long-distance leisure travel. There is already compelling evidence on associations between urban form and long-distance leisure travel to warrant further research, but evidence on causality and plausible explanations is too scarce to inform urban planning policies. However, air travel should inevitably be included in carbon taxation and emission trading schemes. We also suggest that long-distance travel should be included in low-carbon policies at the city level, as well as internationally.

Potentially the strongest influence on urban planning policies lies in the compensation hypothesis and rebound effect research. Establishing how prevalent escape trips are among residents of high-density areas, and under which circumstances they occur, could possibly help to refine urban planning policies. For instance, future research could suggest *the optimal density levels* from the perspectives of both well-being and the environment. It could also provide guidance on *how to maintain high environmental quality while increasing urban density*.

The most common policy recommendation in the rebound effect literature is carbon pricing, including both carbon taxes and emission trading schemes. If the external environmental costs of economic activities were internalized, there would be a market-driven change towards more sustainable technologies, as well as travel behavior and urban structure. For example, high motor fuel taxes make car-dependent residential areas unattractive. However, to avoid rebound effects, the carbon pricing policies should cover all consumption and emissions equally. In addition, particularly related to travel, carbon pricing policies should consider social equity. Income transfers or discounts for lower income groups could guarantee basic transport for all.

Another approach is related to pro-environmental attitudes. It seems that promoting general pro-environmental attitudes might more easily influence such repeated behaviors as recycling or daily travel, but not leisure travel. There is evidence that people

who see themselves as environmentally friendly on a daily basis indulge themselves with long-distance leisure travel, and justify such choices with other pro-environmental behaviors. While carbon pricing policies might be more effective, policy-making should still strive to align travel behaviors to the values of those who are concerned about the environment.

As big technological leaps in fuel efficiency in aviation might not happen soon, changes in behaviors are needed. In some regions (e.g. mainland Europe) many destinations can be reached by trains, even if with a higher time and monetary cost. Choosing alternatives to flying for leisure travel would practically mean changes in destination choices in favor of locations closer to home and reachable with trains. However, for many of the leisure destinations, there is no viable alternative to flying, and lowering climate impacts would require some limitations in leisure mobility, in line with the degrowth scenario and the principle of sufficiency (Xue *et al* 2016).

However, a degrowth approach to travel would require reconsideration of whether and to what extent long-distance leisure travel is a necessity. Currently, leisure travel is by many perceived as essential for quality of life (Dolnicar *et al* 2013), and is considered almost a social right (Richards 1999). Achieving social acceptability of some limitations to mobility would first require modifying the perceived importance of travel for well-being (Reichert *et al* 2016). However, this would be challenging even if well-being is understood in non-materialistic terms (e.g. Soper 2007, Jackson 2017), as leisure travel and the benefits it entails are mainly experiential.

Long-distance travel is likely to increase in the future, both due to growth in income levels in developing countries, reductions in ticket prices and the growing concentration of wealth. To be effective, the policies aimed at limiting long-distance travel should be targeted at the most affluent, well-educated, hypermobile, and predominantly urban minority that contributes most to emissions.

Appendix

Table A1. The impact of urban form aspects on long-distance travel in the reviewed studies with regression analysis.

No	Authors	Year	Country	Range of long-distance travel	Time span	Travel behavior variables (outcome variables)	Urban form aspects (explanatory variables)	Regression coefficient	Control variables
1	Frändberg and Vilhelmson	2003	Sweden	International	12 m	Frequency	Region (Rural)	−0.189	SED, health
3	Holden and Norland	2005	Norway	Leisure travel by plane	(12 m)	Energy use	Housing density	*n.s.*	SED, car, dwelling, SP
							No access to garden	802	
				Leisure travel by car		Energy use	Housing density	*n.s.*	
							No access to garden	213	
4	Næss	2006	Denmark	Weekend trips by car	1 w	Distance	Density	0.08	SED, Car, SP
					1 w		Distance to city center	0.083	
				Trips outside home region	1 w	Likelihood	Density	0.005	
					1 w		Distance to city center	*n.s.*	
				Flight-based holiday trips	12 m	Frequency	Density	0.0026	
					12 m		Distance to city center	−0.14	
12	Holden and Linnerud	2011	Norway	Long leisure travel by plane	(12 m)	Energy use	Residential density	172	SED, Car, 2nd home, SP
							Distance to city center	*n.s.*	
							Private yard	−1017	
13	Dargay and Clark	2012	UK	Domestic	1 w	Distance	Population over 250 K		SED, car, dwelling
							Population 25–250 K	1.87	
							Population 3–25 K	5.58	
							Rural	8.68	
17	Holz-Rau *et al.*	2014	Germany	Long-distance trips with overnight stay	3 m	Heckmann selection	Population density (ref.: <250 inhabitants km^{-2})		SED
							250−<500	*n.s.*	
							500−<1000	*n.s.*	
							1000−<2000	0.065	
							2000−<5000	*n.s.*	
							H 5000	0.078	
							Settlement size (ref.: < 5000)		
							500 000−<1 000 000	0.089	
							H 1 000 000	0.080	

Table A1. *Continued.*

No	Authors	Year	Country	Range of long-distance travel	Time span	Travel behavior variables (outcome variables)	Urban form aspects (explanatory variables)	Regression coefficient	Control variables
							Land-use mix (ref.: poor)		
							Satisfactory	0.084	
							Good	0.063	
							Very good	0.133	
						Heckmann outcome	Population density (ref.: <250 inhabitants km^{-2})		
							250–<500	*n.s.*	
							500–<1000	*n.s.*	
							1000–<2000	*n.s.*	
							2000–<5000	0.082	
							H 5000	0.081	
							Settlement size (ref.: < 5000)		
							500 000–<1 000 000	0.168	
							H 1 000 000	0.150	
19	Reichert and Holz-Rau	2015	Germany		3 m	Participation	Density of the region (ref.: rural)		SED, car
							Urbanized area	*n.s.*	
							Agglomerations	0.123	
							Settlement size (ref.: < 5000)		
							5000–<50 000	*n.s.*	
							50 000–<500 000	*n.s.*	
							> = 500 000	0.432	
							Accessibility of rail station (ref.: >30 min by car)		
							10–<30 min by car	0.156	
							<10 min by car	0.181	
						Distance	Density of the region	*n.s.*	
							Settlement size	*n.s.*	
							Accessibility	*n.s.*	
20	Boucher	2016	USA	Air travel		Emissions	Population density	*n.s.*	SED, SP
21	Reichert *et al*	2016	Germany	All	3 m	Participation	Density of the region (ref.: rural)		SED, Car
							Urbanized area	*n.s.*	
							Agglomerations	0.123	
							Settlement size (ref.: < 5000)		
							5000–<50 000	*n.s.*	
							50 000–<100 000	*n.s.*	
							100 000–<500 000	*n.s.*	
							500 000–<1 000 000	0.234	
							>=1 000 000	0.311	
							Land-use mix (ref.: poor)		

Table A1. *Continued.*

No	Authors	Year	Country	Range of long-distance travel	Time span	Travel behavior variables (outcome variables)	Urban form aspects (explanatory variables)	Regression coefficient	Control variables
							Satisfactory	0.170	
							Good	0.119	
							Very good	0.226	
						Emissions and GWP20	Density of the region	*n.s.*	
							Settlement size	*n.s.*	
							Land-use mix	*n.s.*	
22	Næss	2016	Norway, Denmark	Weekend trips by car	1 w	Distance	Distance to city center	0.836	SED, 2nd home
				All long-distance trips	1 m	Frequency	Distance to city center	*n.s.*	
				Air travel	12 m	Frequency	Distance to city center	−0.289	
24	Bruderer Enzler	2017	Switzerland	Air travel	12 m	Likelihood	Population density	0.094	SED, SP
							Airport access	0.11	
						Emissions	Population density	0.102	
							Airport access	0.119	
27	Czepkiewicz *et al*	2018	Finland	International	12 m	Participation	Urban zone (ref.: central pedestrian zone)		SED
							Intensive public transit zone	−0.57	
							Pedestrian zones of subcenters	−1.03	
							Basic public transit zone	−0.61	
							Car zone	*n.s.*	
						Emissions	Intensive public transit zone	*n.s.*	
							Pedestrian zones of subcenters	*n.s.*	
							Basic public transit zone	−0.28	
							Car zone	*n.s.*	

n.s. = statistically insignificant at $p > 0.05$ level.

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