Iratxe Landa Mata • Øystein Engebretsen •
Rolf Barlindhaug

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Embodied Energy, Costs and Traffic in Different Settlement Patterns

Travel behaviour, housing and location preferences

SINTEF Research

Authors: Iratxe Landa Mata, Øystein Engebretsen and Rolf Barlindhaug
Editors: Selamawit Mamo Fufa and Michael Klinski

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SINTEF Building and Infrastructure
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Preface

This report has been written within the research project "EE settlement – Embodied Energy, Costs and Traffic in Different Settlement Patterns" which is financed by The Research Council of Norway within the Byforsk programme. The project is a broad and interdisciplinary collaboration between SINTEF Building and Infrastructure, Norwegian Institute for Urban and Regional Research (NIBR), Institute of Transport Economics (TØI), Kristiansand Municipality, National Association of Norwegian Architects (by BYLIVsenteret) and two partners from Vienna, Akaryon and IRUB, the Institute of Spatial Planning and Rural Development at BOKU University. This report is written with the contribution from project partners on different topics. The list below includes the names of the authors that have contributed to the various fields:

"Factors influencing residents' energy needs for transport": Iratxe Landa Mata (TØI), Øystein Engebretsen (TØI)

"Housing and location preferences among households": Rolf Barlindhaug (NIBR)

In addition, the report was quality assured by James Kallaos. The editors would like to thank the project partners for their contributions.

Oslo, 17 December 2018

Maria Kollberg Thomassen
Research Manager
SINTEF Building and Infrastructure

Sofie Mellegård
Project Manager
SINTEF Building and Infrastructure

Institute of Transport Economics
Norwegian Centre for Transport Research

OSLO METROPOLITAN UNIVERSITY
NORWEGIAN INSTITUTE FOR URBAN AND REGIONAL RESEARCH NIBR

Abstract

The objective of this report is to provide a state-of-the-art review on relevant existing studies that could be used as a background for tool development and guidelines in the EE settlement project. The report investigates how different dwelling types and settlement patterns affect travel behaviour, including travel mode choice and travelled distances, to create the basis for assessment of residents' transport energy needs in the project. Furthermore, an overview of mobility within and between municipalities for different age groups, and the motives for their movement, is evaluated to provide a basis for housing and location preferences among households. The report highlights the limitations of existing approaches and helps define the scope for further work in the EE settlement project.

Sammendrag

Formålet med denne rapporten er å gi en gjennomgang av "state-of-the-art" for eksisterende, relevante studier som kan brukes som et grunnlag for utviklingen av verktøyet og en veileder i prosjektet "EE Settlement": Rapporten undersøker hvordan ulike boligtyper og bosettingsmønstre påvirker reisevaner, inkludert valg av reisemåte og transportavstander. Dette danner grunnlaget for evalueringen av innbyggernes energibehov knyttet til transport i den videre utviklinga av verktøyet. Rapporten inkluderer også en oversikt over mobilitet innen og mellom kommuner for forskjellige aldersgrupper, og motivene for innbyggernes forflytning evalueres. Det gir et grunnlag for å analysere bolig- og lokasjonspreferanser for husstander. Denne rapporten har satt fokus på omfanget og begrensningene som må vurderes i det videre prosjektarbeidet.

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1. Introduction

The provision of housing for people provides a host of benefits and services, but it also causes a certain amount of environmental and societal disruption. The amount of that disruption, and the impacts caused by it over the life cycle of the housing, depends on a myriad of factors. Besides the different effects from the different housing types, and the quality, materials, and size of the housing itself, there are also other impacts which are often ignored or overlooked. These include the life cycle costs, energy consumption, and greenhouse gas (GHG) emissions which can be attributed to structural and service infrastructure, as well as changes in both demand and capacity for travel and transport. Different housing types may be distributed in different settlement patterns and in different topographic and demographic areas, yielding a wide assortment of expected and observed patterns of impacts.

Most of these issues are not addressed (or only to a minor degree) by existing policies or guidelines, which focus primarily on the efficiency of building-scale operational energy consumption and GHG emissions , while generally disregarding most of the other factors noted above, including other lifecycle stages, occupant behaviour, public costs, and induced demand for traffic and other services (Ding, 2007; DOE, 2012; EC, 2008; EPA, 2012; EU 2002/91/EC, 2003; EU 2010/31/EU, 2010; EU 2012/27/EU, 2012; EU 2018/844, 2018; Gjerstad et al., 2007; Kallaos and Bohne, 2013; Pacheco-Torgal et al., 2012; Szalay, 2007). As increasing efficiency changes the relative effect of embodied versus operational impacts (Koezjakov et al., 2018), it is becoming clear that a valid assessment of different housing settlements needs to take a life cycle perspective, including embodied energy and GHG emissions in addition to the existing variables.

Many studies of residential mobility show that housing preferences, location preferences and housing demand vary with life stages (Clark and Huang, 2003; Barlindhaug, 2010; Barlindhaug ,2013). Gkartzios and Scott (2010) studied counter-urban movement in the greater Dublin area and found that the main motives for moving from the urban to the rural areas were living in a better, larger and cheaper house and that the area was the most appropriate for bringing up children. The area was also associated with a better quality of life, lower density, reduced noise, a slower pace of life, and lack of crime. The pull factors dominated in explaining the move; especially the social environment in rural areas, but also the physical environment and lower house prices. Gkartzios and Scott (2010) point out that this migration pattern is associated with unsustainable patterns of spatial developments. Urban sprawl is developing; nearly 60 percent of counter-urban migration involves a move to a new property. The authors ask for planning interventions in urban areas that could better satisfy the demand by taking more consideration of consumer housing preferences.

Internationally, studies show correlation between settlement structure, accessibility and travel behaviour in cities (see e.g. Ewing and Cervero 2010). Næss (2012) gives an overview and a theoretical discussion of a selection of research in the Nordic countries. In Norway, the Institute of Transport Economics (TØI) has confirmed the correlation through analyses based on data from the national travel surveys combined with registry data. Estimations of generated transport demand enhance calculations of energy and costs related to a settlement, providing a more comprehensive assessment of impacts associated with housing.

Local political and planning authorities seem to focus on satisfying the housing demand of their inhabitants or attracting new inhabitants. This approach will not necessarily result in a sustainable settlement pattern. Municipalities work within, and adapt to, the framework conditions provided by higher-level authorities (regional, national, and supranational). Without strong framework conditions, municipalities which voluntarily follow a settlement pattern that works against their inhabitants' interests may lose inhabitants to neighbour municipalities. Owner occupation is favourably taxed today in Norway, leading to increased demand (by those that can afford it - for living, renting, and speculation). A more neutral taxation policy might influence housing demand, and the ensuing mix of building types in new construction.

1.1 The EE Settlement project

The project *EE Settlement – Embodied Energy, Costs and Traffic in Different Settlement Patterns* addresses these issues and challenges. The main objective is to generate profound basic data on the embodied energy[1] required in different dwelling types and settlement patterns, including associated outside facilities and infrastructure such as roads and services (such as water, electricity and sewage). The project will also assess associated investments, operating costs, operational energy, and generated traffic, as well as the political and societal framework which affects housing development, individual housing preferences, and user decisions. Based on the generated data and assessment results, the project will provide recommendations and a tailor-made web-based tool, to be used for discussion of spatial planning and housing options, as well as for preparation of political decisions. That way, the project will also broaden the basis for the strongly required greenhouse-gas reductions within a sustainable urban development.

The vision for the project is to provide guidelines and tools for municipalities, regional and central authorities, as well as for professionals (e.g. architects and spatial planners) and the public, for assessing the consequences and impacts of different housing development options, taking into account energy need, environmental impact and costs over the lifecycle – not only for the buildings, but including associated infrastructure and transport.

The project is divided into six work packages (WP) that target the main research topics addressed in the project. The overall structure of the work packages, and the connection between them, is shown Figure 1.1.

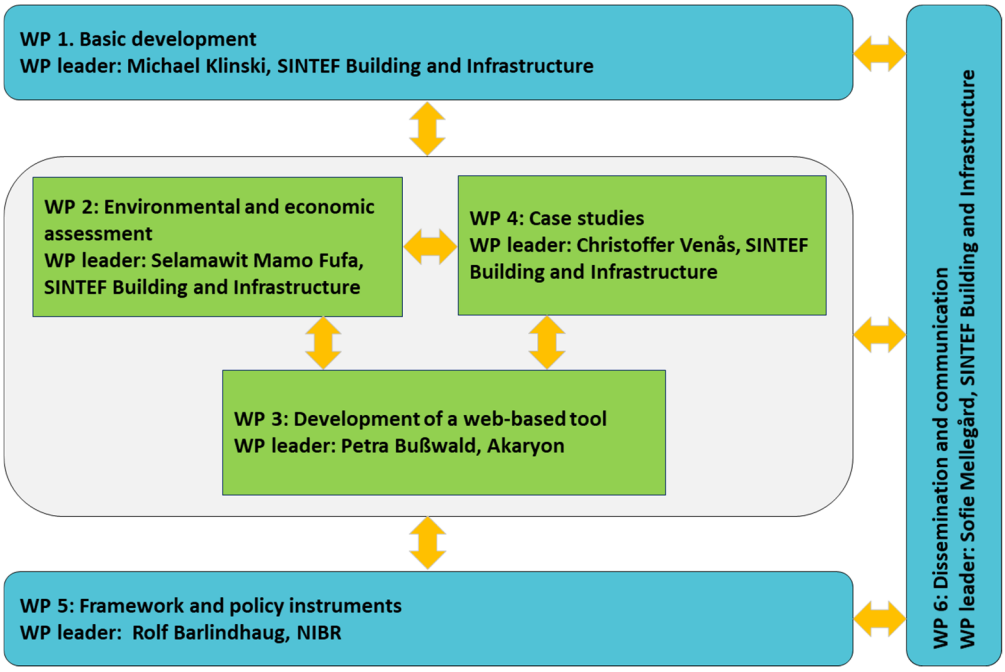

Figure 1.1
EE settlement project organization plan.

The starting point is the development of a basis in WP 1, where needs will be assessed, and the scope defined more precisely. The environmental and economic assessments in WP 2, and the development of a web-based tool in WP 3, will build on this basis, and assessment results will be inputs in the tool. Case studies in WP 4 will, inter alia, be used to validate the tool and contribute to its improvement. WP 5

[1] Embodied energy is the sum of the direct and indirect energy chain needed to produce and support a product or process, including mining, processing, transportation, and assembly or construction (from components and processes with their own embodied energy), expressed in terms of primary energy. Alternative terms include "grey" "indirect" or "supply-chain" energy (see e.g. Treloar, 1998; Lenzen et al., 2008).

examines framework conditions and develops recommendations, based on results from WP 2-4, taking into account the needs identified in WP 1. The results generated in the project will be disseminated in WP 6.

The research partners cover expertise on energy efficiency in buildings, life cycle assessment, infrastructure (SINTEF Building and Infrastructure), transport (TØI), housing and regional development (NIBR and IRUB) and environmental informatics (Akaryon). Contributing public and industry partners are Kristiansand municipality and the BYLIVsenteret. All partners will contribute in all WPs (apart from the technical development of the tool), and there will be a close cooperation between researchers.

1.2 The present report

This report is the partial outcome of a state-of-the-art review performed under WP1, Task 1.1, within the research project EE Settlement. In WP 1, the aim is to create the basis for assessment, examination and tool development. The work includes a state-of-the-art review of current available studies (Task 1.1), a requirement analysis with identification and evaluation of the demands of different municipalities and authorities (Task 1.2), and a definition of the goal and scope of the project (Task 1.3).

The methodology used in this study is based on literature review of existing relevant studies concerning factors influencing residents' energy needs for transport (Chapter 2), and housing and location preferences among households (Chapter 3).

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2. Factors influencing residents' transport energy needs

2.1 Background and purpose of this study

This literature review is part of the project's first work package (Task 1.1), which aims to create the basis for assessment of residents' energy needs for transport and tool development. It is important to note that this document is not a meta-analysis of existing studies, i.e. we do not focus on effect sizes and do not attempt to propose specific regression coefficients. The aim is rather to identify determinants of travel behaviour and, more specifically, of travel mode choice and travelled distances. How and how much individuals travel is essential for estimating the energy needs in transport.

Knowledge gained from reviewed studies will be used later in the project (WP2/Task 2.4) to conduct regression analysis on register- and survey-based travel data from Norway, in order to estimate residents' transport energy needs in different dwelling types and settlement patterns. It will be the results from this empirical assessment that provide the coefficients to feed into the online tool.

Section 2 briefly describes the literature review process. Section 3 reviews main indicators to measure travel behaviour. Section 4 summarizes factors that – according to studies reviewed – influence travel behaviour, with a focus on travel mode choice and travelled distances. We group these factors in three dimensions: 1) socio-economic and demographic, 2) attitudes and preferences and 3) contextual. In this section, we also discuss whether the factors pertaining to these dimensions show positive or negative effects on specific mode choices and travelled distances (though most of studies reviewed focus on explaining car use and vehicle kilometres travelled). To some extent we also discuss the relative strength of factors and dimensions, although this is quite challenging as effect sizes vary across studies and are highly contextual. Section 5 reviews some methodological challenges that are worth considering in the next steps of the project (WP2/Task 2.4), when interpreting studies and estimating residents' transport energy needs in different dwelling types and settlement patterns.

2.2 Methodology

2.2.1 Literature review

The search for relevant literature started by screening studies published by the Institute of Transport Economics (TØI), as well as studies contained in its library. Keywords employed in this search were "travel need(s)", "travel behavio(u)r", "transport mode choice", "car use", "cycling", "public transport use" "walk", as well as corresponding keywords in Norwegian, as many of the studies are in this language.[2]

The second phase of the literature review consisted in screening the references contained in the studies previously retrieved, as well as in reviewing the meta-analysis conducted by Ewing & Cervero (2010) and the reviews conducted by Næss (2012) and Stevens (2017). References considered relevant and not included in either Ewing & Cervero (2010) or in Næss (2012) were reviewed. During this second phase, additional recent publications known to members of the research team were also added: Engebretsen et al. (2018), and Næss et al. (2017a) and (2017b).

The literature review was conducted between November 2017 and January 2018. The review was limited to studies published in or after the year 2000. However, meta-analysis and reviews included in our review (Stevens, 2017; Næss, 2012; Ewing & Cervero, 2010) do encompass studies published before 2000. In total, 63 publications, including both academic papers and reports, were reviewed. Around half of them were retrieved by snowballing. Studies reviewed are not limited to the Scandinavian/Nordic context. The scope was not to conduct a systematic review[3], but to identify factors that may affect travel behaviour and need, thus, to be empirically investigated in subsequent analysis of this project.

[2] «reisebehov», «transportbehov», «reisevane», «reiseatferd», «transportmiddelvalg», «bilbruk», «sykkel(bruk)», «kollektiv(bruk)», «gange», «myk(e) trafikant(er)»

[3] The difference between a systematic and non-systematic review is that a systematic review should have an explicit and rigorous methodology so that its results are accountable and open to criticism (Gough et al., 2013). Our literature review was limited to certain keywords and sources and to studies explaining travel behaviour, but not every single step was planned a

2.2.2 Indicators to measure travel behaviour and energy needs for transport

The indicators mainly used to evaluate travel behaviour are trip frequency, modal shares, travelled distance, and travel time, while travel mode attributes that are usually considered as explanatory variables of travel behaviour are price, availability, comfort and quality.

Trip frequency is usually employed to assess the likelihood to travel. Trips can have different purposes, length, and duration, and can be done by using one mode of transport (e.g. cycle), or by combining different modes (e.g. walk-bus-walk). In transport surveys a trip is usually considered terminated at the location of the trip purpose (Hjorthol et al., 2014; Vågane, 2012), e.g. a work trip ends at work, a shopping trip ends at the shopping location, a home trip ends at home. Trips may be combined into multi-purpose journeys (known as tours or trip chains), e.g. work-grocery-home.

Travelled distance can refer to the total travelled distance (e.g. person kilometres travelled) or by mode (e.g. vehicle kilometres travelled). Travel distances, thus, indicate the extent to which a person travels and, eventually, by which transport mode. At the same time, travel distances can influence travel mode choice, because the need for traveling longer distances usually makes walking and cycling less feasible and the use of public transport more burdensome.

Travel time is influenced by both travel distances and mode. At the same time, the relative travel time is also very important for determining travel mode choice; e.g. the travel time of public transport relative to car is key to increase public transport shares (Engebretsen, 2003; Grue & Holsæter, 2000).

Modal choice indicates the likelihood to use a specific travel mode, as well as the distances travelled by different modes. In the literature reviewed, much attention is given to investigate factors that explain the likelihood of using a car, and distances travelled by car vs. other modes. Car use and vehicle kilometres travelled are also especially relevant for the purpose of this study, i.e. calculating the residents' energy needs for transport. The energy needed for transport on daily trips is normally calculated as a function of the estimated vehicle kilometres travelled. These estimations are normally limited to car use (as driver) because estimation for public transport requires integrating assumptions on occupancy rates. Moreover, the electrification of the car fleet needs also to be considered as electric vehicles have different energy profiles.

2.3 Explanatory dimensions and factors of travel behaviour

Travel-related decisions cannot only be explained by utility functions. Several factors – e.g. preferences; (perceived) uncertainties; contextual constraints; interdependency of choices; learning experiences – need to be considered when studying travel behaviour (Gärling & Young, 2001). How far a person is willing to travel to perform an activity may be motivated by instrumental rationales, as well as by cultural, aesthetic and symbolic preferences, while mode choices are influenced by both individual and contextual factors (Næss, 2012). Qualitative interviews conducted by Næss (2006) in Copenhagen reveal that mode choice is influenced by rationales including time and monetary costs, bodily constraints, flexibility and freedom, a wish for physical exercise, habit, environmental considerations, social norms and the wish for signalling lifestyles. Thus, lifestyle choices can influence travel-related decisions (Eliasson & Martínez, 2001), and everyday mobility is influenced by complex negotiations within households (Jarvis, 2003). Moreover, causal relationships can go either way – structures influence and are influenced by travel behaviour (Næss, 2006).

This section describes factors, which – according to the literature reviewed – have significant effects on travel behaviour, i.e. affect decisions related to whether to travel, how to travel, and distances travelled. The reviewed studies categorize explanatory factors differently, but these can generally be grouped into three dimensions: socio-economic and demographic variables, attitudes and preferences, and contextual factors.

priori and there was certain flexibility when considering whether to include or not retrieved papers, i.e. although the initial intention was focusing on results from regression analysis, descriptive statistics are also included.

The **socio-economic and demographic** dimension includes individual demographic (e.g. gender, age) and socio-economic (e.g. education, occupation, income) characteristics, as well as households' characteristics (e.g. size and composition). This dimension also comprises individuals' access to transport (e.g. car ownership) and travel purposes. Most research acknowledges the importance of controlling for socio-economic and demographic factors when investigating the effect of urban structure and the built environment on travel behaviour. Data on socio-economic and demographic factors which is fed into regression models is generally collected through surveys, in which respondents are asked to report their travel behaviour, as well as travel preferences, and perceived access to transport services and facilities.

The second dimension includes individuals' **attitudes and preferences**. Data on these factors must also be collected through surveys. Respondents can, for instance, be asked about their travel or residential preferences, as well as about their attitudes towards specific travel options and consumption patterns. This dimension also includes norms and personal values. There are fewer studies that integrate factors pertaining this dimension into regression analysis.

The third dimension considers **contextual factors.** This encompasses characteristics of the urban and local environment, such as residential and workplace location, population, jobs and service densities, dwelling types, urban and transport networks forms, parking availability and transport standards. Contextual factors can vary depending on the geographical unit of analysis selected (e.g. neighbourhood, city, regional level). The influence of mega trends and policies is excluded here, although these may also be understood as contextual factors. The policy framework will be explored in WP5 of the project.

There are other factors which have not been considered (e.g. weather). The factors included are those that – according to studies reviewed – have significant (positive or negative) effects on variables describing travel behaviour, such as likelihood to travel, distances travelled and travel mode choice. Effects are considered significant when the associated p-values to regression coefficients are 0.05 or lower. Since some of the studies reviewed use lower confidence thresholds, there may be factors that are not included in this summary, although their effects on travel behaviour are reported as significant in the original studies.

This review is not a meta-analysis, it does not summarize effect sizes, and it therefore does not attempt to quantitatively estimate which are the most influential factors explaining travel behaviour. This is because effect sizes are context dependent and vary across models and the type of variables they comprise. Some studies indicate socio-economic and demographic factors have smaller effects than urban structure on travel behaviour (e.g. Engebretsen et al., 2018; Christiansen et al., 2016; Engebretsen et al., 2011), whereas other studies estimate that variation in travel behaviour is better explained by individual factors than by metropolitan structures and residential zone characteristics (e.g. Schwanen et al., 2004). It is also important to keep in mind that many of the factors described in this review are included in models as control variables whose effects are not investigated in depth. This is specially the case for socio-economic and demographic factors as well as for travel attitudes and residential preferences.

Divergences in absolute and relative effect sizes across studies can be due to differences in model specifications, indicators used, samples, and geographical settings. Therefore, EE-Settlement (WP2) will estimate the effect size of factors suggested as relevant by this review by analysing existing register- and survey-based data from selected cases.

2.3.1 Socio-economic and demographic

Much of the literature review suggests that analyses attempting to explain travel behaviour should control for socio-economic and demographic variables, to prevent that effects of investigated factors (e.g. residential characteristics) are due to individuals and households' socio-economic and demographic characteristics.

The specific socio-economic and demographic variables included in models vary across studies but typically include "having access to car", income, education, occupation, age, gender, households' size and structure and travel purpose. Effect sizes range also across studies.

Generally, models estimate that **having a driving license and access to car(s)** has positive, large and significant effects on travelled distances and car use, although size effects can vary depending on travel purposes and/or areas investigated.

Although studies generally suggest that being a female reduces the likelihood to travel by car and contributes to shorter travelled distances, the effects of **gender** also depend on individuals' employment situation and households' composition (e.g. the presence of children). Moreover, they vary across areas being investigated.

Studies also indicate that individuals and households holding higher **income** show increased car use and travelled distances. However, as there are fewer studies investigating public transport use, walking and cycling, it cannot be ruled out that these income effects are rather a sign of increased mobility (instead of the likelihood to use the car), as suggested by Vibe et al. (2005).

Studies including **education** as an explanatory factor of travel behaviour focus mainly on (car) mode choice. These studies suggest that having high education may reduce the likelihood to travel by car and increase the likelihood to choose other transport modes.

There are relatively few studies including individual **occupation** in regression analysis. Nevertheless, the reviewed studies indicate that being employed (and especially holding full-time employment) increases the likelihood to own a car, to travel and to travel longer distances. Studies also suggest that certain professions (academics, college teachers and those working in non-managerial positions or the public sectors) are less likely to choose the car and more likely to travel by alternative transport modes.

Several indicators and combinations (household size, presence of children, participation in the labour market) are used to account for the effects of **household typology**. Studies reviewed indicate that the presence of children in the household increase the likelihood to own a car, use it, and travel more kilometres. However, the effects of children's presence interplay with those of other members' participation in the labour market. Moreover, the age of children is also a determinant factor.

Last, **travel purpose** influences travel mode choice and distances, as well as mediates the effects of contextual and socio-economic and demographic factors on travel behaviour.

Less clear are the effects of **age** on car use, as well as of these and other socio-economic and demographic variables on the likelihood to walk, cycle and use public transport, and associated travelled distances. Further socio-economic and demographic variables (e.g. **nature of work executed**, **type of sector** in which the individual is employed, and **flexibility of the working** scheme) may also influence travel behaviour. However, these factors are rarely integrated in explanatory models, at least not in those included in the studies reviewed, and therefore there is less evidence on their influence.

Access to car

The operationalization of this factor varies across models and studies. In some models, this factor is introduced in combination with whether respondents hold a driving license (Éllder, 2014; Susilo & Maat, 2007; Vågane, 2000). Some studies investigate the effects of having access to a car "always" (Vibe et al., 2005), "during the whole day" (Vågane, 2000) or "year" (Nordbakke & Vågane, 2007). Other studies analyse this factor at the household level, i.e. whether the household owns a car (Dieleman, 2002; Vågane, 2000), the number of vehicles in the household (Christiansen et al., 2015a; Guo, 2013c; Vibe et al., 2005; Krizek, 2003), or the number of cars per adult in the household (Handy et al., 2005). Car availability index (Schwanen et al., 2004) and different levels of car access (Christiansen et al., 2015b) are also used.

In analyses in which holding a driving license is included as an independent variable, models show that this factor increases the likelihood of using the car (Engebretsen et al., 2018; Christiansen et al., 2015a; 2015b), as well as has positive and significant effects on overall daily travelled distances as car driver (Engebretsen et al., 2018; Handy et al., 2005). This holds true for models in which this factor is integrated in combination with car access/ownership. In such models, positive effects are also reported for distances travelled by car (Éllder, 2014); the (increased) likelihood of using the car (Christiansen et al., 2015b; Susilo & Maat; 2007; Vågane, 2000); and the (reduced) likelihood of using public transport (Nordbakke & Vågane, 2007; Vågane, 2000). Also, a higher ratio of driving licenses to cars in the household increases the likelihood that commuters use other transport modes (and especially public transport) (Vibe et al., 2005).

Based on the literature reviewed, having access to/owning a car has a positive effect on car use (Christiansen et al., 2015b; Susilo & Maat, 2007; Vibe et al., 2005; Schwanen et al., 2004; Dieleman et al., 2002; Vågane, 2000; Grue & Holsæter, 2000) as well as reducing the likelihood to use public transport (Susilo & Maat, 2007; Nordbakke & Vågane, 2007; Engebretsen, 2003; Vågane, 2000). Studies also indicate that having access to a car has positive and significant effects on total travelled distances by car (Éllder, 2014; Schwanen et al., 2014; Dieleman et al., 2002). Moreover, with a higher number of cars available in the household, the likelihood to travel by car increases (Christiansen et al., 2015a; Gundersen & Hjorthol, 2015; Guo, 2013c; Hess, 2001); travelled distances are larger (Guo, 2013c; Handy et al., 2005; Krizek, 2003); and the likelihood to use other transport modes is reduced (Vibe et al., 2005).

Having access to a car shows large and significant positive effect sizes on car use and travelled distances, as compared to other socio-economic and demographic variables (Christiansen et al., 2015a; Éllder, 2014; Guo, 2013c; Susilo & Maat, 2007; Schwanen et al., 2004; Dieleman et al., 2002; Hess, 2001; Vågane, 2000). However, size effects can vary depending on travel purposes and/or areas being investigated. In Sweden, Éllder (2017) finds that not having access to a car reduces the daily commuting distance travelled by car less than the daily distance travelled for service related trips. Dieleman et al. (2002) shows that, in the Netherlands, the effect of car ownership on the likelihood to use the car in work and shopping trips is larger than the effect on leisure trips (as compared to using public transport). And, in Engebretsen et al (2018), the effect of having a driving licence on the likelihood to drive to work is positive and significant in the urban region of Stavanger/Sandnes (but not in the urban region of Bergen, Trondheim and Oslo), whereas the significance of the effect on commuting distances varies across cities, and on whether the model accounts for residential or workplace location characteristics.

As having access to a car is a key factor, some studies have also explored which factors influence car ownership. Factors explaining car ownership include age, gender, income, having a driving license, occupation, household size and structure, attitudes, distance to the city centre, local densities, neighbourhood characteristics, parking availability, public transport standards, and type of dwelling (Christiansen et al., 2015b; Guo, 2013a; Guo, 2013b; Cao et al., 2007; Vågane, 2006a; Næss, 2005; Vågane, 2000). These factors can be understood as variables that have both direct effects and indirect effects on travel behaviour through car ownership.

Age

The effects of age on travel behaviour vary depending on the investigated variable, the geographical setting, and the trip purpose. Vågane (2000) finds that age has a negative and significant effect on the likelihood to travel in Norway. The effect of age is also negative and significant on overall daily travelled distances as a car driver in the urban regions of Oslo and Stavanger/Sandnes (Engebretsen et al., 2018), as well as on commuting distances by car in these two cities during weekdays (being the effect positive at weekends) (Næss et al., 2017a) and in the Netherlands (Schwanen et al., 2004). Engebretsen et al. (2018) also report negative and significant effects of age on commuting travel distances in the urban region of Stavanger/Sandnes when accounting for residential location variables. However, the effects of age on commuting distances as car driver are positive and significant in this urban area, as well as in the urban regions of Oslo and Bergen, when they account for workplace location variables (Engebretsen et

al., 2018). Negative effects of age on overall vehicle travelled kilometres are also observed in selected neighbourhoods in Northern California (Handy et al., 2005).

The effects of age on travel mode choice are inconclusive. Age has a positive and significant effect on the likelihood to travel predominantly by car in the urban regions of Oslo and Trondheim, as well as to commute as car driver in these cities and Bergen (when accounting for workplace location variables) (Engebretsen et al., 2018). Positive and significant effects of age on car use are also reported in Engebretsen et al. (2011) and in Christiansen et al. (2016). However, there is also evidence of negative effects of age on car use in Norway (Vågane, 2006a) and the Netherlands (Schwanen et al., 2004). Differences could be due to the type of variables these studies account for. While Engebretsen et al. (2011) and Christiansen et al. (2016) account for variables such as population and jobs densities at residential location, the latter two studies (Vågane, 2006a; Schwanen et al., 2004) account for more general urban structural variables.

Nordbakke & Vågane (2007) find that those aged 67 and older are more likely to use public transport for commuting, when accounting for parking, public transport accessibility, and distance between the dwelling and the workplace. Yet, in the Netherlands, Susilo & Maat (2007) find that being 65 and older reduces the likelihood to choose both car and public transport as travel mode for commuting, compared to non-motorized transport modes choices, when accounting for commuting distances and distances to different transport modes, urbanization level, population size, and job accessibility. Vågane (2006b) finds positive and significant effects of age on walking, regardless of travel purpose.

The relative influence of age (vs. other factors) depends on the type of variables the analysis controls for, the area investigated; and the age interval (in the models where this variable is not continuous). Moreover, some studies find no significant relationship (Næss et al., 2017b; Boarnet & Crane, 2001). Nevertheless, results suggest that the analysis should account for age as an explanatory factor. Furthermore, age can be integrated in the analysis at the household level (e.g. number of people under a certain age/children living in households).

Gender
Vågane (2000) finds no significant effects of gender on the likelihood to travel in Norway, but several studies indicate that being a female reduces the likelihood to travel by car and travelled distances by car. Studies at both city and national level in Norway show that being a female reduces the likelihood to drive, both generally and when commuting (Engebretsen et al., 2018; Christiansen et al., 2016; Christiansen et al., 2015a; Vågane, 2006a). In line with these results, being a male increases the likelihood to drive, also generally and when commuting (Christiansen et al., 2015b; Gundersen & Hjorthol, 2015; Vibe et al., 2005; Vågane, 2000).

It is important to note that most of the studies focus on explaining car use as driver and not as passenger. Women could use the car as much as males, but this would be not reflected if they are travelling as passengers. Results from Vibe et al. (2005) indicating that being a man reduces the likelihood to travel in a car as passenger suggest this.

Being a female also reduces the likelihood to drive to work in the Netherlands, but not for single employed females with no children, and for females that live in one and two worker family households (Schwanen et al., 2004). In such cases, the sign of the regression coefficients is positive. Evidence of effects for other travel purposes are scarce. Being a male increases the likelihood to drive on shopping trips in Norway (Vågane, 2000), while being a female increases the number of non-work travel trips in Southern California (Boarnet & Crane, 2001).

Effects on the travel mode choices other than car are less clear. Being a male reduces the likelihood to commute by public transport in Norway (Vågane, 2000), as well as in the ten largest Norwegian urban areas for those who are employed, hold a driving license, and live in households with access to car (Vibe et al., 2005). Being male reduces the likelihood to use the car and public transport (compared to non-motorized travel modes) in commuting trips in the Netherlands (Susilo & Maat, 2007). There are also

studies which find no significant effects of gender on the likelihood to commute by public transport (Nordbakke & Vågane, 2007), cycle, or walk (Vibe et al., 2005). When it comes to daily trips in Norway, Vågane (2006b) found that being a woman increases the likelihood to walk at least one daily trip. When it comes to travel distances, studies suggest that being a female reduces overall daily travelled distances as car driver in the urban regions of Oslo, Bergen, Stavanger/Sandnes, and Trondheim (Engebretsen et al., 2018); as well as in Sweden (Éllder, 2014).

Focusing on commuting distances, results from Ireland show that being a male increases commuting travelling distances (Schuttelworth & Gould, 2010). However, the effect of gender on commuting distances seems to vary depending on the urban area investigated and household structure. Regression analysis conducted by Engebretsen et al. (2018) indicate that being a female reduces commuting travelled distances in the urban region of Oslo, Bergen, Stavanger/Sandnes (but has no significant effects in Trondheim), while Næss et al. (2017b) find that being a female significantly reduces commuting distance by car in the urban region of Stavanger, but find no significant effects in the urban region of Oslo. Moreover, based on data from the Netherlands, Schwanen et al. (2004) show that being a female reduces commuting distances by car, but that this effect depends on the type of household in which individuals live. It is still negative for females in one-worker and two-worker family households, but positive for females in two-worker couple households. This indicates the importance of household structure.

Income

Income is usually measured at the individual and household level. Vance & Hedel (2008) investigate the effect of income on vehicle ownership and on total distance travelled, for non-work-related trips during weekdays in Germany at the zip code level but find no significant effects. Generally, studies indicate that income contributes to an increased likelihood to travel by car, as well as distance travelled by car.

Household income has a positive and significant effect on weekly driving distances in the urban regions of Oslo and Stavanger, both on weekdays and weekends (Næss et al., 2017a); on kilometres travelled by car (as driver) in the Netherlands for both work, shopping, and leisure trips (Dieleman et al., 2002); and on weekly vehicle kilometres travelled in Washington (USA) (Krizek, 2003). Studies also find positive effects of personal income on overall daily travelled distances as car driver in the urban region of Oslo, Bergen, Stavanger/Sandnes, and Trondheim (Engebretsen et al., 2018); on commuting distances as car driver in the urban region of Oslo (Næss et al., 2017b); and on commuting distances by car in the Netherlands (Schwanen et al., 2004). Moreover, there is evidence that income has a positive and significant effect on overall travelled distances in Sweden (Éllder, 2014) and Washington (USA) (Krizek, 2003).

Income effects are not always significant across locations and vary with travel purpose. Engebretsen et al., (2018) find significant effects of income on commuting (one-way) distances only in the urban regions of Oslo and Stavanger/Sandnes (not in Bergen and Trondheim), and only when accounting for workplace location characteristics (not when accounting for residential location characteristics). Næss et al. (2017b) do not find significant effects of income on commuting distances as car driver in the urban region of Stavanger.[4]

When it comes to modal choice, studies show that household income has positive effects on the likelihood to use the car (as driver) in the ten largest Norwegian city-municipalities (Christiansen et al., 2015a); in Oslo and Akershus (Hanssen & Engebretsen, 2006). Household income also has a positive effect on choosing the car (as driver) in Netherlands (Dieleman et al., 2002); on choosing the car (as driver and passenger) in the New York City region (Guo 2013c); and on choosing the car – vs. transit – (either to drive alone or ride in a carpool) in work trips in Oregon (Hess, 2001).

[4] Note that only workforce participants with one-way commuting distances less than 100 km (Oslo) and 50 km (Stavanger) were included in the analysis.

Personal income has also positive effect on the likelihood to travel by car (as driver) (Christiansen et al. 2016); in Norwegian urban areas with at least 50000 inhabitants (Engebretsen et al., 2011), on the likelihood to commute as a car driver, and to predominantly travel as car driver in the region of Oslo, Bergen, and Stavanger/Sandnes (but not in Trondheim) (Engebretsen et al., 2018). Personal income has a positive effect on the likelihood to commute as a car driver in Netherlands (Schwanen et al., 2004) and in the urban regions of Oslo, Bergen, and Trondheim (Gundersen & Hjorthol, 2015), although the latter effects are only significant up to a certain income level (less than 300,000 Norwegian Kroner).

Studies investigating the effects of income on other transport modes is scarce. In the Netherlands, Dieleman et al. (2002) find that income has negative effects on the choice of cycling/walking (vs. public transport use) for work, shopping, and leisure trips, but positive effects on distances cycled for all travel purposes, as well as on distances travelled by public transport (with the exception of shopping trips, for which effects are negative).

Some studies reviewed find no significant effects of income. This is the case for the number of non-work-related trips in California (Boarnet & Crane, 2001); for car and public transport use in commuting trips in the Netherlands (as compared to non-motorized travel modes) (Susilo & Maat, 2007); and for vehicle kilometres travelled by households (as driver) in the New York region (Guo, 2013c). This could be due to contextual factors and/or the type of variables included in the model. The latter is illustrated by analysis conducted by Vibe et al. (2005), which finds that the effects of income and education on travel mode choice disappear once the model accounts for factors such as whether respondents work in the private sector, have a company car, and company agreements on car use. Moreover, the effects of income may change once certain income levels are reached (Boarnet & Crane, 2001 and Gundersen & Hjorthol, 2015), or depending on whether households have access to garage or not (Guo, 2013c).

Last, some studies suggest that household income has also positive and significant effects on the number of tours (trip chains) and number of trips per tour in Washington (USA) (Krizek, 2003), as well as on the number of home-based tours (as driver) in the New York City region (Guo 2013c).

Education

In the models reviewed, education is not included as often as gender and income. Yet, the effects of income on travel behaviour can "hide" indirect effects of education on travel behaviour through income.

Based on national travel data for Norway, Christiansen et al. (2016) report that having high education has a negative and significant effect on the likelihood to drive a car on trips that start at the dwelling. The effect of having high education is also negative and significant among those living in households that have access to a car in Oslo, Bergen, Trondheim, and Stavanger/Sandnes (Christiansen et al., 2015b). Engebretsen et al. (2018) find that holding a university degree has a negative and significant effect on the likelihood to commute as a car driver in Oslo, Stavanger/Sandnes, and Trondheim (also negative in Bergen, but not significant). The same study reports on negative and significant effects on the likelihood to travel predominantly by car, but only in Oslo.

Findings from studies based on data from the Netherlands point in the same direction. There, high education decreases the likelihood to commute by car, compared to commuting by using non-motorized transport modes (Susilo & Maat, 2007), and having low education increases the likelihood to commute as car driver (Schwanen et al., 2004). However, the direction of the effects (positive or negative) may vary depending on travel purpose. Dieleman et al. (2002) analyse Dutch national travel data and find that having middle education (as compared to college or higher education) increases the likelihood to use the car on both working and leisure trips, but not on shopping trips. When shopping, having lower education reduces the likelihood to use the car. The likelihood to use the car also decreases among people with lowest education (elementary) when shopping and conducting leisure trips (for commuting trips the effect is still positive but non-significant).

Some studies have also investigated the effect of education on other mode choices. Based on national travel data for Norway, Nordbakke & Vågane (2007) find that having high education increases the

likelihood to commute by public transport among people living in households with access to car, while Vågane (2006b) reports that having high education (college/university) increases the likelihood to walk at least one trip. Data analysis from Netherlands also suggests that high education increases the likelihood to commute by public transport, with reference to non-motorized transport modes (Susilo & Maat, 2007). Still in the Netherlands, having low education generally reduces the likelihood to use public transport, cycling, and walking, though the effect on choosing to cycle and walk is not significant for those with middle-low education travelling for leisure purposes, and positive for commuters with elementary education (Dieleman et al., 2002).

There are fewer studies among those reviewed that investigate the effect of education on travelled distances, and regression coefficients seem to be less significant across sites investigated. Nevertheless, the effects seem to be positive rather than negative. This may indicate that while having high education may reduce the likelihood to travel by car, those who do travel by car and have high education tend to travel longer distances than those with low education.

Engebretsen et al. (2018) find that holding a university degree has a positive and significant effect on overall daily travelled distances as car driver in Oslo and Bergen (but not significant in Stavanger/Sandnes and Trondheim, though also positive), as well as on commuting travel distances but only in Oslo (the effect is positive but not significant in Bergen, Stavanger/Sandnes, and Trondheim). Næss et al. (2017a) find that holding a university degree has a positive and significant effect on vehicle kilometres travelled during weekdays in Stavanger (but not in Oslo). In the Netherlands, having lower education than college reduces commuting travelled distances by car (Schwanen et al., 2004), while travelled distances by cycling and walking increase among those with middle-low and elementary education (Dieleman et al., 2002). There are also studies that find no significant effects of education on total travelled distances in Sweden (Elldér, 2014), on the number of non-commuting trips in Southern California (Boarnet & Crane, 2001), and on the likelihood to conduct all daily trips by walking (Vågane, 2006b).

It is important to keep in mind that, at least in the Nordic cities, jobs that require a skilled workforce (both public and private) are usually located in central areas where there is good accessibility with public transport and car use is constrained. This implies that there may be structural reasons explaining the lower car use levels among more educated employees. In other words, some of the negative effect of education on car use may actually be due to the location of workplace in central areas.

Occupation

There are relatively few studies assessing how much of the variance in travel behaviour is explained by individuals' **occupation.** Based on national travel data from Norway, Vågane (2000) shows that being employed increases the likelihood to travel; that holding a full-time job increases the likelihood to own a car; and that having a flexible work schedule increases the likelihood to commute by public transport, while working in shifts reduces the likelihood. Further analysis from Norway, but limited to the ten largest Norwegian urban regions, finds that those working in the public sector have a lower likelihood to commute by car, but higher likelihood to walk or cycle (Vibe et al., 2005); and that working in the academic/university/college sector decreases the likelihood to commute by car (Gundersen & Hjorthol, 2015).

Effects of occupation type are also found in analyses conducted abroad. Working and holding high status occupations increases both vehicle travel kilometres in Northern California (Handy et al., 2005) and commuting distances in Ireland (Schuttelworth & Gould, 2010). Having a non-managerial job reduces the likelihood to drive and ride in a carpool when commuting, as compared to using public transport (Hess, 2001).

Occupation may also be investigated at the household level and under consideration of its structure, as described later in this document. Moreover, it is important to keep in mind the indirect effects upon travel mode choice of structural factors through workplace location in central areas, as described in previous section ("Education").

Household characteristics: size and composition

This is a factor which is complex to summarize because studies use different categorizations to integrate it in regression analysis: some consider age and household size (in terms of household members) and the presence of children, while others also combine these elements with members' participation in the labour market. Moreover, thresholds to account for the presence of children and seniors may vary. Although studies reviewed do not always find significant effects of household characteristics on overall travel (Elldér, 2014), vehicle kilometres travelled (Guo et al, 2013c), and mode choice (Susilo & Maat, 2007), and effects vary across studies, the results indicate that this is an important factor that needs to be considered. As Jarvis (2003) argues, daily mobility is influenced by complex negotiations within households, and these depend on the household size and composition, as well as on individual and collective space-time constraints.

Engebretsen et al. (2018) analyses data from the urban regions of Oslo, Stavanger/Sandnes, Bergen, and Trondheim, and finds that the number of children in the household has a positive and significant effect on overall and commuting travelled distance as car driver. However, effects are not significant across all urban regions investigated, and vary depending whether models include residential or workplace location variables. Similarly, Næss et al. (2017b) find that the number of children aged below seven increases vehicle kilometres travelled when commuting in the urban regions of both Oslo and Stavanger. However, the number of household members aged 18 and older has only a significant and negative effect on the same variable in the urban region of Stavanger but not in Oslo.

Analysis on data from the Netherlands indicate that the number of household members below 18 and above 64, the number of working females and males, and those holding a university or college degree, have a positive effect on overall travelled distances for non-work-related trips. Dieleman et al. (2002) and Schwanen et al. (2004) investigate the effect of household typologies based on household size, participation in the labour market, and presence of young children. Results reported by Dieleman et al. (2002) indicate that two-worker-families travel fewer kilometres by car than one-worker-families, and that two-person-households, in which one of them works, and other household typologies travel more vehicle kilometres for shopping and leisure trips.

Krizek (2003) analyses panel data from 430 households who relocated in selected counties in Washington (USA) and finds that the number of adults living in the household reduces the number of tours (trip chains), the numbers of trips per tour, as well as overall and vehicle kilometres travelled. Analysis of this data shows also that the number of children increases the number of tours but reduces the number of trips, whereas no significant effects are found on person and vehicle kilometres travelled (Krizek, 2003).

When it comes to car ownership, analysis of travel data from Norway shows that living with people under 18 years in the household or with a partner increases the likelihood to own a car (Vågane, 2000). Car ownership is also positively influenced by household size and number of workers in the household, according to data from Northern California analysed by Cao et al. (2007). Data from New York analysed by Guo et al. (2013a; 2013b) show more nuanced results, namely that the effect of the number of children may only be significant on the likelihood to own the second car, though this may vary across sub-samples depending on whether households have access to off-street or on-street parking. Effects of participation in the labour market is only significant for full-time employees on owning two or more cars in households that have access to off-street parking.

When it comes to travel mode choice, evidence from major Norwegian urban regions suggests that the presence of children in the household affects car use. Engebretsen et al. (2018) report that the number of children has a positive and significant effect on the likelihood to drive a car both generally and for commuting trips, although, effects are not significant across cities and vary depending whether models include residential or workplace location variables. In an analysis of travel data from the three largest Norwegian urban regions, Gundersen & Hjorthol (2015) show that, compared to households whose youngest child is aged between 13 and 17, single households are more likely to use the car on commuting

trips, whereas households whose youngest child is aged below 12 and couples with no children are less likely to do so. Analysis on data from large Norwegian urban areas shows that having a partner that works at least 25 hours a week increases the likelihood to walk, cycle, or use public transport when commuting (Vibe et al., 2005).

Data from the Netherlands analysed by Dieleman et al. (2002) shows that household types can have different effects on mode choice depending on whether they travel for working, shopping, or leisure activities. Compared to one-worker-families, one- or two-worker households are less likely to choose the car for working and shopping trips but more likely to do so for leisure trips, as well as more likely to walk/cycle for shopping and leisure activities, and more likely to use public transport for shopping (the effect on non-motorized transport for work trips was not significant) (Dieleman et al., 2002). Two-worker families are also more likely to use the car on shopping trips, less likely to commute by public transport and more likely to use transit, walk and cycle for performing leisure activities (the effect on other types of trips was not significant for this household type) (Dieleman et al., 2002). Schwanen et al. (2014) find that females are less likely to use the car when commuting, but not if they work and have children. In this case they are more likely to use the car. On the other hand, an analysis conducted by Susilo & Maat (2007) finds no significant effect of household size and the presence of children on either car or public transport use for commuting, as compared to the use of non-motorized transport modes.

Studies analysing data from the New York region report that the number of workers in the household has a negative and significant effect on car mode choice both as a driver and a passenger, whereas household size has a positive effect on the number of home-based car tours (Guo, 2013c). Oppositely, based on data analysis from the Oregon and Washington, Hess (2001) finds that household size has a negative effect on driving alone, as compared to transit use. Boarnet & Crane (2001) find no significant effects of household size and presence of children under 16 on car use for non-work travel related trips in Los Angeles, but they do find that effects are positive on car use in San Diego.

Travel purpose

We generally travel to conduct activities that fulfil our needs. Qualitative interviews conducted by Næss (2006) among residents in the Copenhagen metropolitan area show that selecting the location of the activity mainly seeks to balance time-geographical constraints with the wish of finding the best facility or concentration of facilities. Performance of certain activities may require travelling longer distances, whereas for other purposes people may not need or may not be willing to travel far. Travel distances as well as the type of activities may influence travel mode choices. Studies reviewed indicate that travel purpose influences travel behaviour as well as mediates on the effects of other influential factors on travel behaviour.

Based on descriptive analysis of travel survey data, Engebretsen (2003) reports that travel purpose is among the factors which – along with densities, destinations' and residential location, transport resources and accessibility, relative travel times, parking facilities and mixed land use – affect the mode choices. Data from the National Travel Survey 2013/2014 (Hjorthol et al., 2014) illustrate differences between trips conducted for different travel purposes. According to this data, each person performs an average of 0.69 commuting trips per day, each of these trips are in average 16.3 km long, and most are conducted by driving a car (61 per cent), followed by public transport (16 per cent) (Hjorthol et al., 2014). The same survey shows that each person performs an average of 0.88 shopping trips per day, and that an average shopping trip is 7.7 km long. Although most of shopping travelling also occurs by driving (62 percent), people walk more than when commuting (21 percent vs. 11 percent) (Hjorthol et al., 2014). Leisure and visiting trips are more distinct, with 41 per cent of trips being conducted by driving, 33 per cent on foot, and with larger average lengths (23.4 km per trip).

It is important to keep in mind that these figures refer to individual trips (i.e. each trip is considered terminated at the location of the trip purpose (Hjorthol et al., 2014; Vågane, 2012). However, daily travel is usually organized into trip chains, as illustrated in Vågane (2012). Her analysis of national travel data shows that trips chains starting and ending at home consist in average of 2.38 trips. This implies that travel related decisions pertaining to one trip may be influenced by the other trip. For example, we may

have chosen to travel by transit to work from home in the morning but, since we have some errand on our way back home from work that it is difficult to reach by transit, we choose to drive to work. Work and shopping trips are typically included in trip chains: 61 and 48 percent of trip chains with at least four trips include, respectively, a shopping and a work-related trip.

Results from regression analysis reported in studies reviewed suggest that travel purpose influences total travelled distances (Elldér, 2014), as well as mode choice (Christiansen et al., 2015b; Nordbakke & Vågane, 2007; Vågane, 2006a; Vibe et al., 2005; Grue & Holsæter, 2000; Vågane, 2000).

Based on national data from Norway, Vågane (2006a) reports that the likelihood to drive a car is lower for leisure and visiting trips, but higher for shopping and "caring" trips than for commuting trips. Having errands on the way to or from work (e.g. picking/bringing children from/to school, shopping, other errands) increases the likelihood to choose the car (Christiansen et al., 2015b; Grue & Holsæter, 2000; Vågane, 2000). Having errands on the way to or from work decreases the likelihood to travel by public transport, cycle or walk (Nordbakke & Vågane, 2007; Vibe et al., 2005). Results from Sweden also show that daily travel distances are longest for work-related (32.3 km) trips, compared to service (18.9 km) or leisure (23.5) trips[5] (Elldér, 2014).

Travel purpose may also mediate the effects of other factors on travel behaviour (Elldér, 2014; Cao et al., 2009; Sælens & Handy, 2008; Hjorthol, 2003; Dieleman et al., 2002; Meeurs & Haaijer, 2001). Hjorthol (2003) conducts analysis of survey-based data from three cohorts (30–35, 45–50 and 60–65 years) in Oslo, Bergen, and Trondheim, and finds that although people living in central locations use the car less, the dwelling location does not play a role in the frequency and mode choice for trips related to outdoor activities (e.g. walks in forests) and visits to relatives and friends (visits to relatives and friends are mainly done by car, regardless of where respondents live).

Analysis of data from Sweden shows that the effect of the residential location on travelled distances is strongest for trips that are performed in contracted (e.g. work trips) and committed time (e.g. trips to grocery, health and child care) compared to those performed in leisure time (Elldér, 2014). Studies based on data from the Netherlands indicate that the effects of the residential environment depend on the transport mode investigated and on travel purpose (Meeurs & Haaijer, 2001), and that the effects of age and education on mode choice may be different depending on travel purpose (Dieleman et al., 2002). Also, studies from California indicate that the effect of the built environment on travel behaviour may vary depending on travel mode, trip purpose, how the characteristics of the built environment are being measured (local vs. regional), and population characteristics (Cao et al., 2009). For instance, in travel decisions related to work trips, workplace characteristics may be more important than residential characteristics (Engebretsen et al., 2018). Sælens & Handy (2008) also find that the effects of the built environment are different for utilitarian walking (walking as a mode of transportation) than for recreational walking. Their analysis on data from Australia, Belgium, the Netherlands, Portugal, and the United States shows that density, distances to non-residential destinations, and land use mix positively influence utilitarian walking, but that these factors show little or no influence on recreational walking.

2.3.2 Travel attitudes and residential preferences

This dimension could be expanded to encompass a broader range of factors such as values, norms, emotions, perceived control, evaluations and perceptions. These factors are also named as psychological (Eriksson, 2009) and motivational (Steg et al., 2001) factors, and they may influence attitudes, preferences and travel behaviour. For instance, regression analysis on data from Netherlands shows that including an explanatory variable measuring awareness about the contribution of car use to environmental pollution increases the variance of weekly car mileage explained by the model, compared to the model that only included socio-economic and demographic variables (Steg et al., 2001).

[5] As described by Éllder (2014), the Swedish National Travel Survey categorizes trips according to their main purpose, meaning that one trip may actually be a trip chain. This, among other things, implies fewer journeys per day.

However, the literature search did not retrieve many studies which include attitudinal factors when investigating the effects of contextual and socio-economic and demographic variables on travel behaviour. Steg et al. (2001) argue that this dearth of literature may be linked to the disciplines (transport and urban economics) that have mainly contributed to transport forecasting models, as well as to the lack of data on these types of factors and on whether these change over time.

Nevertheless, some of the regression analyses reviewed indicate that travel attitudes (Cao et al., 2007; Handy et al., 2005) and residential preferences (Næss et al., 2017a; 2017b; Handy et al., 2005) influence travel behaviour. Moreover, attitudes, preferences and motives also depend on socio-economic and demographic factors (Berge & Amundsen, 2001), as well as on contextual variables (Steg et al., 2001). These dimensions, thus, interplay when influencing travel behaviour. Evidence on the influence of travel attitudes and residential preferences is summarized below.

Travel attitudes
Among studies reviewed, only two of them consider travel attitudes: Handy et al. (2005) and Cao et al. (2007). Both use the same data but investigate different travel related variables. The data is obtained from a cross-sectional and longitudinal survey among individuals who participated in the decision of residential selection living in four traditional and four sub-urban neighbourhoods in Northern California. Besides travel attitudes, both include socio-economic variables, preferences for neighbourhood characteristics, perceived neighbourhood characteristics and accessibility measures as explanatory variables.

Handy et al. (2005) investigate what explains weekly vehicle distances. Their findings show that having **pro-bike/walk** and **pro-transit behaviour** contribute to reduce travelled distances, while **car-dependent-** and **safety-of-car attitudes** increase them[6]. When Handy et al. (2005) incorporated travel attitudes into the model, results showed that accessibility measures and perceived characteristics had no significant effect on distances travelled by car. However, analysis on changes in these variables as a result of moving (i.e. changing residence) showed that changes in the built environment, and especially, increases in accessibility, along with attitudinal factors (car-dependent and pro-bike/walk-attitude) contribute to less driving (Handy et al., 2005).

Cao et al. (2007) investigated factors that explain car ownership and came to similar results. Their model that employs cross-sectional data and includes travel attitudes and neighbourhood preferences, shows no effects of residential characteristics on car ownership. As expected, both **car-dependent-** and **safety-of-the-car attitudes** have positive effects on car ownership. The model using longitudinal quasi-longitudinal data (data from those moving before and after) shows that the number of business types within 400 metres have a negative effect on car ownership, even after accounting for all other types of explanatory factors, including residential preferences and travel attitudes.

Both studies (Cao et al., 2007; Handy et al., 2005) suggest that the effects of the built environment found in the quasi-longitudinal studies could be due to changes in attitudes rather than to the built environment (as both studies consider that attitudes remain constant, which may not necessarily be the case). Also, a descriptive analysis conducted by Grue & Holsæter (2000) shows that people who like traveling by public transport and do not like to drive a car in the city are less likely to use the car. It must also be noted that travel attitudes towards specific transport modes depend also on **perceptions of transport mode attributes**.

Berge & Amundsen (2001) conducted a literature review to investigate attitudes and preferences to different modes of transport. Although their study does not investigate causal relationships, the review shows that travel time (and especially door-to-door perceived travel time), accessibility (which strongly depends on frequency), reliability (which is related to delays), comfort (e.g. seat availability; cleanness), safety, price, and information are important transport attributes forming attitudes towards transport modes. Ruud et al. (2001) identify public transport user preferences to improve public transport in six

[6] These attitudinal variables resulted from a factor analysis.

middle large urban regions (Kristiansand, Moss, Skien/Porsgrunn, Tromsø, Ålesund and Drammen). They find that key factors are walking time to/from stop, frequency, travel time, interchanges and whether the stop/station has a shed. Furthermore, the study shows that the youngest and oldest users show demand the most.

Nossum (2003) investigates public transport user preferences for service improvement in Oslo and Akershus by employing stated preferences. Factors (ranked from highest to lowest) are: having a direct interchange, time spent at interchanges, travel time (standing), walk time to/from station/stop, frequency, and travel time (seating). Nossum (2003) also compares results for Oslo from 2002 with those from 1992 and finds minor changes. In 2002, walk time to/from station and frequency are valued lower, while time spent at interchanges and travel time (seating) are valued higher. Although having a direct interchange is valued lower, this factor remains as the most important.

Residential preferences

People prefer or value proximity to places where they can realize their needs and activities. These preferences can be different: it may be proximity to workplace, places that are considered "good for children", outdoor preferences, or proximity to the public transport. Besides the studies already mentioned above (Handy et al., 2005; Cao et al., 2007), two studies conducted in Norway by Næss et al. (2017a; 2017b) have considered residential preferences to explain travel behaviour. This is important because studies investigating the influence of contextual factors such as residential characteristics and urban form have been criticized for not accounting for self-selection (residential preferences) that produce spurious effects.

Based on cross-sectional data from Northern California, Handy et al. (2005) find that **preferences for outdoor and spaciousness**[7] have positive effects on vehicles kilometres driven, and that both **residential preferences for accessibility**[8] **and safety**[9] have a negative effect on vehicle kilometres driven, i.e. an increase in those preferences contributes to a decrease or smaller increase in vehicle kilometres driven after moving. Based on the same dataset, Cao et al. (2007) find that **residential preferences for both outdoor and spaciousness, and accessibility,** influence car ownership. While the former contributes to an increase in car ownership, the later contributes to a reduction. Analysis of data from those moving (i.e. changing residence) find no significant effect of accessibility preferences on car ownership but shows that an increase in preferences for **outdoor and spaciousness** is associated with a decrease or smaller increase in car ownership.

In Norway, Næss et al. (2017a; 2017b) analyses data collected through questionnaires and interviews of residents of the urban regions of Oslo and Stavanger, to investigate overall driving distances in the whole week, weekdays, and weekends, and commuting distances by car. The studies explore the influence of built environment characteristics, while considering residential preferences (based on factor analysis) and socio-economic and demographic characteristics. A major contribution of the study is that it illustrates that the effects of explanatory variables on travel behaviour vary across sites being investigated.

Næss et al (2017a) show that residential preferences for **investment**[10] have a positive effect on overall driven distances in the urban region of Oslo and Stavanger, while residential preferences for **proximity-to-transit** and **proximity-to-workplace** have negative effects[11]. However, in Næss et al. (2017b) the analysis reveals no significant effects (at the 0.05 level) of preferences for residences that are **good-for-children**, allow for **physical exercise factor,** are **close to transit** and are **favourable for investment** on commuting driven distances in Stavanger. In Oslo, both preferences for residences that are **good-for-**

[7] Statements behind this factor are related to the preferences for large back yards, large front yards and lots of off-street parking (garages or driveways)

[8] Based on statements on the easiness to access downtown, regional shopping malls and freeways, the proximity of shopping areas and other amenities and the availability of public transport

[9] Based on statements related to the quietness, safety, street lightning, crime rates and traffic level of neighbourhoods.

[10] Based on statements related to social problems, investment and property management.

[11] In Stavanger, the effect of investment is only significant at the 0.05 level on weekdays, while in Oslo, the effect of proximity-to-workplace is only significant also on weekdays.

children and that allow for **physical exercise factor** have a negative effect on commuting driven distances, while preferences for residences **close to transit** residences have a positive effect[12]. The latter two are, however, not significant at the 0.05 level.

2.3.3 Contextual factors

This dimension is focused on characteristics of the urban structure. According to a literature review conducted by Stead & Marshall (2000), factors pertaining to the urban pattern include distance from the residence to the urban centre; settlement size; land use mix; provision of local facilities; density; proximity to main transport networks; availability of residential parking; road network type; and neighbourhood type. The relative importance of urban structural factors on travel behaviour compared to individual preferences and socio-economic and demographic variables is highly relevant for policy makers, who wish to know the extent to which housing and land use policies can influence travel behaviour. Much of this discussion focuses on self-selection, which is discussed in section 2.4.2.

Despite ongoing discussions on the relatively importance of urban structure on travel behaviour, there is enough evidence on the effects of contextual factors on travel behaviour (Engebretsen et al., 2018; Næss et al., 2017b; Næss, 2012; Strand et al. 2010; Cao et al., 2009; Engebretsen, 2003). Urban structural factors are relevant, even when their effect sizes are reduced after accounting for socio-economic characteristics (Stead & Marshall, 2000), and/or attitudes and preferences are included in models (Cao et al., 2007; Handy et al., 2005; Krizek, 2003). Explanatory contextual factors included in models vary across modes and some may be specific to certain modes. For instance, for increasing the likelihood of choosing public transport, factors that improve aspects such as travel, waiting, and walking times, seat availability, inter-exchanges, and shelter may be influential, as these are key factors described by travellers (Nossum, 2003; Ruud, Tuveng & Norheim, 2001). For choosing to cycle, specific infra-structure design (e.g. sufficient space to prevent conflicts with other travellers; continuous connections, regulation at crossroads) may exert larger influence on improving safety and therefore increasing cycling shares than other more general contextual measures (Høye et al., 2015).

Despite these differences, there is little doubt of the influence of the **distance from the dwelling to the city centre** on travel mode choice. City centres generally account for lower car use, compared to out-skirts. The negative effect of central locations on car use is, at the same time, explained by other con-textual variables. City centres offer better public transport and less parking availability. There are relatively fewer studies investigating location effects other than those of dwellings. Yet, **workplace location** also influences travel behaviour, and the effects may be larger than those of residential location. A further factor which clearly influences travel behaviour is **parking availability and pricing**. Studies indicate that parking availability at both the dwelling and destination (e.g. workplace) clearly increases the likelihood to own and use a car, especially when parking spaces are for free**.**

Most of the reviewed studies also suggest that population and job **densities both at urban scale and at the place of residence** decrease the likelihood to use the car and increase the likelihood to use public transit. Although less investigated, densities at destinations seem also to be influential. Less clear are the effects on travelled distances

There are also relatively fewer studies investigating **land use mix** and diversity of choice, although these also seem to affect travel behaviour. **Public transit service standards** can be measured by distance to public transit stops, as well as availability, frequency, and quality of services. Studies indicate that shorter distances from the dwelling to public transit stops, as well as good and frequent services, de-crease the likelihood to use the car and increase the likelihood to use alternative transport modes. However, not all studies find significant effects, and some suggest that effects may be relatively small.

[12] The authors explain the negative effect of preferences for neighbourhoods that are "good for children" on commuting distances by arguing that these respondents "*tend to work closer to home*", while they explain the positive effect of "proximity to transit" on commuting distances by arguing that *"good accessibility by transit makes it easier to overcome distances"* (Næss et al., 2017b, p. 11).

Less clear are the effects of **dwelling types** and **urban form**, partly because the literature search retrieved relatively few studies exploring the effects of these factors. There may be other factors affecting travel behaviour which are not described below, such as composite measures of accessibility and connectivity, as well as specific characteristics related to street design or road infrastructure. We have neither described regional contextual factors that go beyond the urban/metropolitan area.

Residential location and distances
Residential location is generally operationalized at the urban level by indicators measuring distance to the downtown area, and at more local level by indicators measuring distance of residential location to second- and third order centres (where services and jobs are concentrated).

Several studies from Norway and abroad indicate that the distance from the residential location to the concentration of facilities (which is generally located at the city centre but may also be at second-order centres) positively influences travelled distances and/or car use (Engebretsen et al., 2018; Næss et al., 2017a; 2017b; Stevens, 2017; Christiansen et al., 2015a; Elldér, 2014; Strand et al., 2013; Næss, 2012; Engebretsen et al., 2011; Ewing & Cervero, 2010; Næss, 2006; Hanssen & Engebretsen, 2006; Engebretsen, 2005; Næss, 2005; Schwanen et al., 2004; Næss, 2004; Hjorthol, 2003). This holds also true in studies that control for socio-economic and demographic factors (Engebretsen et al., 2018; Christiansen et al., 2015a, Elldér, 2014); attitudinal/preference variables (Næss et al., 2017a; 2017b; Næss, 2006), as well as in the relatively fewer studies that control for self-selection (Næss, 2012; Næss, 2004).

However, it is important to keep in mind that this influence may occur indirectly through car ownership and transport attitudes (Næss, 2006), and that effects may vary depending on which variables are included in the model. For instance, Christiansen et al. (2016) find a positive effect of distance from the dwelling to the city centre on the likelihood to drive the car, although this is not significant in this multivariate analysis. Yet, the effect would probably had been significant if variables such as distance from workplace to the city centre, density, and parking facilities had not been included in the regression.

Moreover, the effect of distance from the dwelling to second and third-order centres is less consistent across cities. In Engebretsen et al. (2018), distance from the dwelling to second-order centre contributes to increased overall daily travelled distance as car driver, and longer commuting travel distances in the urban regions of Oslo and Stavanger (but not in Bergen and Trondheim), as well as to predominantly travel as a car driver, but only in Oslo. Although these effects are lower than those of distances to the city centre, they are still quite strong for the urban region of Stavanger/Sandnes in the case of commuting distances. Distance from the dwelling to third-order centres shows only positive and significant effects on commuting travel distances in Bergen. The positive effect of distance from the dwelling to second-order centres found in the urban region of Stavanger is also reported by Næss et al (2017a) on vehicle travelled distances, and by Næss et al. (2017b) on commuting distances, but such effects are not found in the Oslo urban region.

Furthermore, it is not quite clear whether the influence of distance from the dwelling to the city centre applies regardless of travel purpose. Moreover, the effects of location on distances travelled may vary depending on whether we look into weekdays or weekend travel (Næss et al., 2017a). The review conducted by Næss (2012) shows that it may apply to both work and non-work-related trips. But specific empirical studies reviewed by Næss (2012) – e.g. Hansen & Masud (2001) – indicate that distance to the city centre has no effect on travelled distances for non-routine leisure trips. Also, the analysis conducted by Hjorthol (2003) on data from Oslo, Bergen, and Trondheim shows that the location of the dwelling does not play a role in the frequency or modal choice for trips related to outdoor activities (e.g. walks in forests) and visits to relatives and friends.

Recently, there has been an increased interest in assessing the influence of characteristics within the neighbourhood scale. This may certainly play an important role, especially for trips conducted within the neighbourhood, as illustrated by Meeurs & Haaijer (2001). Their analysis of Dutch travel data suggests that the effects of the residential environment on car use are greatest for trips related to daily

activities such as grocery shopping, and lowest for commuting trips, which – according to the authors – are mainly explained by personal characteristics. Engebretsen et al. (2018) argue that most daily trips are to destinations that lie outside the neighbourhood, and that travel distances are more likely to be influenced by residential location within the urban area than by neighbourhood/local characteristics. They also argue that the centric vs. peripheric residential location influences characteristics at the neighbourhood scale. Residential location has, thus, both direct and indirect effects (through neighbourhood characteristics) on travel-related decisions. Furthermore, Næss (2004) argues that the importance of smaller and local centres will vary depending on the degree to which people limit their activities to the local environment, as well as on other urban structural factors.

Workplace location

According to Næss (2012) there are fewer studies in the Nordic region investigating the effect of these variables on travel behaviour. His review shows that proximity of the workplace to downtown areas and public transport generally contributes to lower shares of car commuting and higher shares of commuting travel by public transport, bicycle and walking, although the influence of location on commuting distances may vary depending on the type of jobs.

Analyses of both national and city level travel data show that longer distances from the destination to the city centre significantly increase car use (Christiansen et al., 2016; Christiansen et al., 2015a). Similarly, Vibe et al. (2005) analyse travel data from the ten largest Norwegian urban areas and find that working in the city centre or at a central location and within 5 kilometres of the dwelling's location reduces the likelihood to commute by car. Moreover, working in the city centre or at a central location increases the likelihood to commute by public transit, whereas working within 5 kilometres of the dwelling's location increases the likelihood to cycle and walk to work). It should be, however, noted that increased distances from the dwelling to workplace may also contribute to increase commuting travel by public transit, as reported by Nordbakke & Vågane (2007) and Vågane (2000).

Further site-specific analysis in Norway suggest similar effects. Strand et al. (2013) find that having a workplace that is located close to the centre or within 2 kilometres from the dwelling reduces the likelihood of car use within the Oslo region. Engebretsen et al. (2018) also find positive effects of the distance of workplace to the city centre on both commuting distances and the likelihood to commute by car in the urban region of Oslo, Bergen, and Stavanger/Sandnes. In Trondheim the effect is also significant and positive on commuting distance but not on the likelihood of commuting by car (Engebretsen et al., 2018). Næss et al. (2017b) analyse survey-based data from the urban regions of Oslo and Stavanger and find that distance from the workplace to the main city centre contributes to increase commuting distances in both cities. Engebretsen (2005) analyses geo-located travel data and finds that those travelling to central destinations use the car less and public transit more, as compared to those who travel to destinations located outside the inner city. And, descriptive analysis conducted by Engebretsen (2003) on survey-based travel data for Oslo, Bergen, and Trondheim indicate workplace location (in relation to the city centre) affect travel mode choice. When interpreting results, it is important to keep in mind that most of the studies investigating the effect of workplace location also include residential location, and that this affects the strength of the effects.

Land use mix

Proximity to facilities and places where activities can be performed is not always the most important factor. People may value more the variety of choices (Næss, 2012). The meta-analysis conducted by Ewing & Cervero (2010) indicates that both land-use mix and jobs-housing balance contribute to reduce vehicle kilometres travelled, whereas these two variables increase the likelihood of walking. However, the review conducted by Stevens (2017) indicates that land-use mix may instead contribute to more driving, once self-selection is accounted for. Otherwise, the effect is negative.

Based on travel data from the urban region of Oslo, Bergen, and Trondheim, Gundersen & Hjorthol (2015) find that availability of a grocery store within 500 meters, and availability of 5.000 jobs within 1500 meters significantly reduces the likelihood to commute by car. However, they also find that the availability of a school and a kindergarten within 500 meters is positive and not significant. Also, the

analysis conducted by Christiansen et al. (2015a) on travel data from Norwegian urban areas with at least 50,000 inhabitants captures the negative effect of functional mix on car use. In their analysis, both the number of workplaces and the number of employees in retail within 500 meters around the dwelling have a negative effect on the likelihood to drive. In Oslo, Bergen, and Trondheim, descriptive analysis conducted by Engebretsen (2003) finds that cycling shares are higher in densely populated areas with short distances and mixed land use.

Pooley et al. (2009) analyse data from four British cities (Lancaster, Leeds, Leicester, and Worcester) and find that diversity and number of land-use activities have a positive effect on the frequency of walking trips for non-work-related purposes during a typical week. Also, analysis of data from the Dutch National Travel Survey shows that the ratio of jobs to residents within Daily Urban Systems (DUS) reduces the likelihood to drive to/from work (Schwanen et al., 2004). Handy et al. (2005) analyse longitudinal data from eight neighbourhoods in Northern California and find that the more grocery stores, pharmacies, and theatres within a certain distance to the dwelling are, the shorter the weekly vehicle travelled distances. Last, based on survey-based travel data from Seattle, McCormack et al. (2000) find that respondents living in mixed land use neighbourhoods travelled less than residents living in adjacent areas as well as in inner and outer suburbs, in spite of socio-economic characteristics.

Local and regional densities
Several studies have investigated the effects of urban and local densities on travel-related decisions. These densities mainly refer to the concentration of population, jobs, built area, and services at either the local or urban scale. According to Næss (2012), studies applying to the Nordic region have focused on investigating the influence of densities at either the urban or local area level but not at the local scale, which has received more attention in international studies.

Urban/municipal level
In his review, Næss (2012) finds two studies investigating the influence of population densities at the urban level in the Nordic region. Both – after controlling for socio-economic and demographic variables – show negative relationships between population densities at this level and energy use for transport, i.e. the higher the population densities, the lower the energy use. The meta-analysis conducted by Ewing & Cervero (2010) also indicates that housing and population densities negatively influence vehicle kilometres travelled, whereas these two densities positively influence public transit use and walking, which is also positively influenced by job densities. The review conducted by Stevens (2017) finds the same effect for job densities. Also, analysis of Dutch travel data shows that job densities within Daily Urban Systems (DUS) have a negative effect on commuting distances by car and that residential densities at the municipal level reduce the likelihood to drive to/from work (Schwanen et al., 2004). Negative effects of population densities on commuting distances are also reported in Ireland by Schuttelworth & Gould (2010).

Some studies do not explicitly account for densities, but control for the size of settlements and whether they are urban or rural. We choose to mention them here because large urban areas tend to have higher densities. National travel data from Norway shows that living in Oslo and other large urban municipalities significantly decreases the likelihood to own a car, compared to living in rural areas (Vågane, 2000), although the sign and the significance of the influence on car use seems to depend on the travel purpose. Vågane (2000) also finds that living in Oslo increases the likelihood to walk, compared to the next six largest Norwegian cities, but find otherwise no significant effects on walking. The same data analysis shows that living in Oslo, large urban municipalities, and surrounding municipalities increases the likelihood to commute by public transit (Vågane, 2000). However, the analysis conducted by Nordbakke & Vågane (2007) on national travel data for Norway shows that living in Bergen, Trondheim, Stavanger, surrounding municipalities, and middle-sized urban areas reduces the likelihood to commute by public transit, compared to living in Oslo. Analysis of national travel data also shows that living in Oslo, Bergen, Trondheim, and Stavanger significantly decreases the likelihood to own a car, compared to the next largest Norwegian cities (Vågane, 2006a), where the effect on car use is only significant in Oslo. Findings reported by Elldér (2014) based on data from the National Swedish Survey also indicate that travel distances for trips starting at home (excluding trips which are not made

on a regular basis) are shorter in larger and medium-sized urban areas, compared with non-urban areas (Elldér, 2014).

Studies find similar effects in the Netherlands as well. Susilo & Maat (2007) analyse data from the National Travel Survey and find that living in highly or very highly urbanized areas, as compared to low urban areas, reduce the likelihood to commute by car and increase the likelihood to commute by public transport. Findings reported by Dieleman et al. (2002) also show that people tend to commute shorter distances by car in medium-sized cities, but longer in suburban/rural areas, compared with the three largest cities. However, their analysis also shows that living in both medium-sized cities and sub-urban/rural areas also increase the likelihood to commute longer distances by public transit. The same analysis also shows that living in a medium-sized city or suburban/rural area increases the likelihood to use the car, but it also increases the likelihood to cycle, compared with the three largest cities and having as reference public transit (Dieleman et al., 2002).

A descriptive analysis conducted by Engebretsen (2003) on longitudinal survey-based travel data indicates that population density at the urban level contributes to reduce the extent of travel, but also that differences in car use are greater within than between cities, i.e. implying that densities at the local area level also play a key role in shaping travel behaviour. His analysis of national and regional geo-located travel data shows that, in urban areas with at least 20000 inhabitants, the proportion of daily travel by car decreases with increasing population density, while the share of public transit increases (Engebretsen, 2005).

Densities at the place of residence

A national travel data analysis in Norway shows that both land-use and population densities at the place of residence significantly reduce the likelihood to drive the car in trips starting at the dwelling (Christiansen et al., 2016). Analysis of data from the ten largest Norwegian municipalities also shows that land-use, population, jobs, and retail job densities at the place of residence significantly reduce the likelihood to drive (Christiansen et al., 2015a). Also, analysis of survey-based travel data conducted by Engebretsen et al. (2018) finds negative and significant effects of population and job densities at the place of residence on the likelihood to predominantly travel as car driver and on overall daily travelled distance as car driver in the urban regions of Oslo, Bergen, and Trondheim (but no significant effects in Stavanger/Sandnes). The effects of these densities on the likelihood to commute as driver, are significant and negative in Oslo, Bergen, and Trondheim, while no significant effects are found on commuting distances in either of the four cities. Analysis of travel data from the urban regions of Oslo and Stavanger conducted by Næss (2017a) shows that population and job densities have a negative effect on vehicles kilometres travelled in the Oslo urban region, but they find no significant effects in the Stavanger urban region. Negative effects of densities at the place of residence on car use are also found when including all urban areas with at least 50000 inhabitants by Engebretsen et al. (2011), and in Oslo and Akershus by Strand et al. (2013) and by Hanssen & Engebretsen (2006).

In his review, Næss (2012) also finds evidence of positive effects of dwelling densities on public transit use and negative effects on travelling distance on weekdays. However, the effects of local densities disappear in some of studies, after controlling for distance to the city centre. There are further studies, among those reviewed, that do not find significant effects of densities at the place of residence. For instance, Næss (2006) does not find a significant effect of population and job densities at the place of residence on travelled distances, distances travelled by car and shares, when analysing data from Copenhagen. Guo (2013c) also finds no significant effect of job densities on vehicle travelled distances and number of car tours in selected New York neighbourhoods, but does find negative effects of job density on the likelihood to use the car (either as driver or passenger) and of population density on the likelihood to have three or more home-based car tours. Boarnet & Crane (2001) find no significant effects of population, retail, and service densities on the number of non-work-related trips in Southern California. And Tretvik (2008) finds no significant effects of population and job densities on cycle shares.

Moreover, Guo (2013c) finds a positive effect of population densities on vehicle travelled distances, and the likelihood to use the car in commuting trips (not significant) in selected neighbourhoods in New York. Pooley et al. (2009) investigate the effects of other type of densities, i.e. node and street density from four British cities (Lancaster, Leeds, Leicester, and Worcester) on the frequency of walking trips for non-work-related purposes during a typical week and find positive effects. Moreover, studies indicate that densities may also influence car ownership. Based on survey-based travel data and interviews, Næss (2005) finds that the probability of having at least one car increases with low land-use density, once socio-economic factors and attitudes are controlled for, in the Copenhagen region. Data analysis from New York also indicates that high population densities at the place of residence may decrease the probability to own one or more cars, for those who live in households that only have on-street parking (Guo, 2013a).

Densities at the destination
Some of the studies also investigate the effects of densities at the destinations (e.g. workplace, retail). A national travel data analysis in Norway shows that land-use densities at the destination significantly reduce the likelihood to drive the car in trips starting at the dwelling (Christiansen et al., 2016). Moreover, analysis of data from the ten largest Norwegian municipalities shows that land-use, job and retail job densities at the destination significantly decrease the likelihood to drive (Christiansen et al., 2015a). The same study also reports that job densities at the workplace significantly decrease the likelihood to commute by car; and that population and job densities at the destination significantly decrease the likelihood to drive (Christiansen et al., 2015a). Engebretsen et al (2018) find that population and job densities have a negative and significant effect on the likelihood to commute as a car driver in the urban regions of Oslo, Bergen, Trondheim, and Stavanger/Sandnes. In Oslo, Bergen, and Trondheim the effect of densities at the workplace are stronger than the effects of densities of the residential location, whereas in Bergen the effects of densities at the workplace are weaker. The effects of population and job densities at the workplace on commuting distances are positive and significant in the urban regions of Oslo, Bergen, and Trondheim. In other words, people are less likely to drive when they work at places with high residential and jobs densities, but that they may travel over longer distances. Furthermore, the review conducted by Næss (2012) indicates that shopping centres and workplaces located in high density local areas contribute to less car use.

Parking availability and pricing
Studies reviewed indicate that parking availability and pricing affect car ownership and mode choice, although it may be argued that this is the result of self-selection (i.e. households owning a car would be less likely to live in a dwelling with restricted or costly parking spaces). There are relatively fewer studies investigating the effects of this factor on vehicle or person travelled distances. When it comes to car ownership, data analysis from Oslo, Bergen, Trondheim, and Stavanger/Sandnes shows that having private parking at home increases the likelihood of owning a car (Christiansen et al., 2015b). Similar effects are found abroad. Analyses of survey and online street view data from households in the New York region show that off-street parking supply increases the likelihood to own one, two, or three or more vehicles, while crowded on-street parking spaces reduces it (Guo, 2013a; 2013b). For households with only on-street parking, crowding of these facilities significantly reduces the likelihood to own one car, but no significant effect is found for owning two or more cars (Guo, 2013a). A third paper presented by Guo (2013c) on analysis of this dataset also shows that only having access to street parking significantly reduces the number of car tours and vehicle kilometres as well as the likelihood to use the car in the first trip of a home-based tour, both as a driver and passenger, but that this effect is not significant for commuting trips (Guo 2013c).

When it comes to mode choice, studies reviewed also show that parking availability and pricing both at the dwelling and the destination (e.g. workplace) affect car use. In Norway, an analysis of national travel data shows that not having an own parking space at the dwelling reduces the likelihood to drive (Christiansen et al., 2016). Similarly, data from the ten largest Norwegian municipalities shows that the longer the distance to the parking facilities at the dwelling, the lower the likelihood to drive (Christiansen et al., 2015a), while data from Oslo, Bergen, Trondheim, and Stavanger/Sandnes indicate that the higher

the number of parking facilities at the dwelling, the higher the likelihood to use the car, and that the longer the distance to the parking space the lesser this likelihood (Christiansen et al., 2015b).

When it comes to parking availability at the destination, analyses show that the likelihood to commute by car is higher for those who have parking facilities at the workplace, and highest for those who have these facilities for free (Christiansen et al., 2015a; Gundersen & Hjorthol, 2015; Vibe et al., 2005). Access to free parking also reduces the likelihood to use public transit, walk, and cycle to work (Vibe et al., 2005), while reduced parking availability and parking fees at the workplace increase the likelihood to commute by public transit (Nordbakke & Vågane, 2007). Moreover, Vibe et al. (2005) find that having access to free parking reduces the likelihood to switch from commuting as a car driver to commuting by public transportation. Also, a descriptive analysis conducted by Grue & Holsæter (2000) shows that expensive parking facilities and problems with finding parking at the destination contributes to not using the car.

Examples of the influence of parking availability and pricing on car use are also reported for the Netherlands by Meeurs & Haaijer (2001), UK by Rye et al. (2006) and USA by Guo (2013c), Hess (2001) and Weinberger et al. (2009). Meeurs & Haaijer (2001) analyse data from the Dutch Time Use Study and find that easy parking and having a shed, storage or garage has a positive effect on the number of trips made by car. Hess (2001) analyses data from the Oregon and Southwestern Washington Activity and Travel Behaviour Survey and finds that parking costs reduce the likelihood to commute by car, both as car driver and as rider in carpool, as compared to public transit. Rye et al (2006) conduct a survey among employees in Edinburgh's city centre to assess the potential modal change as a result of expanding the boundaries of the Control Parking Zone. Their results show that on-street parking control could contribute to reduce private car use by 21% for commuting trips, while increasing bus use by 13.2%, train by 12.7%, and walking by 14.3%. Weinberger et al. (2009) investigate car use of residents of two neighbourhoods in New York City (Jackson Heights and Park Slope) who commute to Manhattan. Surprisingly, their results show that the neighbourhood (Park Slope), which should expectedly show a higher car share – because of higher car ownership rate, higher median income, lower population density, higher transit time relatively to travel time by car and higher number of residents that work in the destination area – did not. By comparing the availability of off-street parking spaces in both neighbourhoods, Weinberger et al. (2009) conclude that lower accessibility to parking space (12% against 31%) may explain the results.

Public transit service standards

Explanatory variables employed to investigate the effect of public transit service standards on travel behaviour include distance to public transit stops, as well as availability, frequency and quality of public transit services, mainly with reference to the place of residence. Based on analysis on data from Norway, Vågane (2000) finds that the likelihood of travel by public transport increases with the quality of the transit service. National travel data regression analysis also indicates that public transit service quality may exert some influence on car ownership as well as on car use (Vågane, 2000; 2006), although regression coefficients vary depending on the categorical value of the quality of public transit service. The introduction of light rail in Bergen in 2010 has shown that upgrading of the transit services may significantly increase the use of public transport (Engebretsen et al., 2017). Increased service frequency generates more travels by public transport, the effect being greater than by price reductions (Brechan, 2017). Analysis of survey and online street view data from households in the New York region indicates that distance to the subway station significantly increases the likelihood to own one, two, or three or more vehicles in households with off-street parking, but no significant results are found for households with only on-street parking (Guo, 2013a).

When it comes to travelled distances, analysis of data from Germany and from selected Norwegian cities indicates that better accessibility to public transit may contribute to reduce travelled distances by car. Engebretsen et al (2018) find that having frequent public transit services[13] at the place of residence has a negative and significant effect on overall daily travelled distances by car in the Oslo urban region,

[13] Number of departures per hour within 1.5 km from the dwelling between 07–09 on weekdays

although they do not find significant effects in any of the other three urban regions investigated (Bergen, Stavanger/Sandnes, and Trondheim). Data analysis from the German mobility panel indicates that the longer the walking distance to public transit, the higher is the likelihood to own a car and the longer the distance people are likely to drive (Vance & Hedel, 2008). However, a review conducted by Stevens (2017) suggests that the effect of the distance to the nearest transit stop is relatively small, though significant.

Within the studies reviewed, regression models accounting for public transit service standards generally attempt to explain mode choice rather than person or vehicle travelled distances. In Norway, analysis of travel data shows that having bad public transit service increases the likelihood to drive (Christiansen et al., 2016), that having a good or very good public transit service reduces this likelihood (Gundersen & Hjorthol, 2015), and that anything other than very good accessibility to public transit services decreases the likelihood to use these services (Nordbakke & Vågane, 2007). Other site-specific analyses suggest similar effects. Engebretsen et al (2018) find that having access to public transit at the place of residence decreases the likelihood to travel and commute by car in the urban regions of both Oslo and Trondheim, although they find no significant effects in the urban regions of Bergen and Stavanger/Sandnes. Based on travel data collected from Oslo, Bergen, Trondheim, and Stavanger/Sandnes, Christiansen et al. (2015b) find that having good public transit services reduces the likelihood of car use. Also, analysis of data from the ten largest Norwegian municipalities shows that having a bad public transit service increases the likelihood to drive, while a high frequency of public transit decreases the likelihood to drive on intra-urban trips (Christiansen et al., 2015a). Similarly, Vibe et al. (2005) find that having at least four public transit departures per hour and two public transit services within 15 minutes walking distance reduces the likelihood to commute by car in the ten largest Norwegian urban regions, while increasing the likelihood to commute by public transit. Having at least two public transit departures within 15 minutes walking distance also increases the likelihood cycle or walk to work (Vibe et al., 2005). Analysis of data from Oslo and Akershus also shows that the longer time respondents need to reach the public transit stop, the higher the likelihood to use the car (Hansen & Engebretsen, 2006). Engebretsen et al., (2017) show that the probability of travelling by the light rail in Bergen drops rapidly around 600 metres from the stops, corresponding to the findings in a travel and attitude survey before the opening of the light rail line in 2010 (Christiansen et al., 2010).

Descriptive analysis of travel data confirms that public transport standards are important to shape our travel habits. Based on national and regional travel data, Engebretsen (2005) argues that door-to-door travel time by public transit (as compared to travel time by car) affects mode choice, and travel data for Oslo, Bergen, and Trondheim also indicates that accessibility to public transit affects mode choice (Engebretsen, 2003). On the other hand, our search also retrieved some studies which find no significant effects of variables measuring public transit service standards on car ownership (Christiansen et al., 2015b), car use (Susilo & Maat, 2007; Guo, 2013c), and travelled distances by car (Guo, 2013c).I It should also be noted that longer distances to public transit stops can also contribute to more walking, as reported by Ewing & Cervero (2010).

Dwelling types

The literature search retrieved few studies investigating the effect of dwelling type on travel behaviour. Christiansen et al. (2015b) analyse factors affecting car ownership among residents in Oslo, Bergen, Trondheim, and Stavanger/Sandnes. Their results show that those living in apartment blocks have significantly lower probability to own a car compared with people living in detached houses. Their corresponding regression analysis to explain car use does not include the type of dwelling as an explanatory factor. However, Christiansen et al. (2015b) also conducted correspondence analysis on the dataset. They find that dwelling type is associated with different levels of car use. More specifically, the analysis shows that living in an apartment block is associated with being young, a relatively low household income, being single, frequent public transport departures, relatively long way to parking, and low car use. Factors associated with living in a semi-detached house are having a relatively high household income, short way to parking and reserved parking spaces, car ownership, and using the car three to four days a week. Last, living in detached houses is associated with high material living standards and a high car use.

For planning purposes, Hansen & Engebretsen (2006) developed and tested a method for estimating car traffic related to different housing types based on data from national travel surveys (linked to building information) and local traffic counts. The local traffic counts were conducted in four residential areas (two of them characterized by the presence of detached houses and two by blocks of flats) 10 and 26 kilometres from the city centre in the Oslo region. The results from both methods show that, on weekdays, households living in residential areas characterized by detached houses on average have a higher number of car trips per household than households residing in residential areas of blocks of flats. However, there are no significant differences in the number of car trips produced in comparable housing types in Oslo and Asker. These differences are also supported by data from a survey conducted among respondents in two of the four residential areas in Oslo (one characterized by small detached houses and one by block buildings).

Analysis of data from California find that renting housing significantly reduces the probability of owning a car compared to those who own housing (Cao et al., 2007), and that the number of travel trips not related to work tend to increase if the residence is owner-occupied (Boarnet & Crane, 2001). In the Netherlands, Meeurs & Haaijer (2001) analyse data from the Dutch Time Use Study and find no significant effects of the type of dwelling (in detached, semi-detached and terraced houses, compared to those that live in flats) on the number of trips made by travel mode. They also investigate the effects of having a private garden, having an attractive view, and having a front door on a cycle route, and find that having a non-private garden significantly increases the number of bicycle trips, and an unattractive view significantly increases the number of total trips and those made by public transit. No other significant effects at the 0.05 level were found.

Urban and transport network forms

Studies which have conducted analysis in different sites show that the influence of the distance from residential location to the city centre depends on whether the site under investigation has a monocentric or a polycentric structure (Engebretsen et al., 2018; Næss et al., 2017a; 2017b). Næss et al. (2017b) investigate the effect of built environment characteristics on travelled distances and mode choice in Oslo and Stavanger while accounting for socio-economic and demographic variables and residential preferences. They find that the positive effect of the distance from dwelling to the main city centre on commuting distances is stronger in the monocentric urban area of Oslo than in the polycentric urban area of Stavanger, where the distance to the second order centre (Forus) exerts a greater influence (Næss et al. (2017b). Cross-sectional analysis of the same dataset conducted by Næss et al (2017a) shows that the effect of the distance of residential location to the city centre is the most influential factor of all the built environment characteristics in both cities. However, while in monocentric Oslo the effect size is much larger during weekdays than at weekends; in polycentric Stavanger the effect of this variable has a similar size during weekdays and at weekends. Besides, driving distances in the Oslo urban region are also influenced by population and job densities, whereas in Stavanger these factors do not play a role but distance to Sandnes does (Næss et al., 2017a). An analysis conducted by Engebretsen et al. (2018) on data from the urban region of Oslo, Stavanger/Sandnes, Bergen, and Trondheim finds, however, that second-order centres have a positive and significant effect on overall car travel distances in both polycentric Stavanger and monocentric Oslo. According to the review conducted by Næss (2012), very few studies have investigated the influence of local street network pattern on travel behaviour in the Nordic region. One of them shows no effect once controlling for distance to the city centre and individual variables. The other study is limited to the propensity of children to walk to school and shows lower propensity to walk in neighbourhoods with grid street patterns and mixed traffic.

Our literature review retrieved one paper that investigates the influence of network and local-street network types located in Dutch cities with different morphological urban forms and road transport networks on travel behaviour (Snellen et al., 2002). The study conducts multi-level analysis on data collected from individuals residing in neighbourhoods[14] with specific characteristics, while accounting

[14] Selected neighbourhoods had low correlations with indicators of residential location relative to the city centre, main intercity train station and regional shopping centers. Other neighbourhood characteristics included in the model were location

for personal and household characteristics. Results show that the effects of urban form and network types are rather limited. This is in line with the argument sustained by Næss et al. (2017b), i.e. that network design at the street level may have some influence on mode choice for trips within the neighbourhoods but that they are unlikely to influence mode choice and travelled distances to activities outside the neighbourhood.

2.4 Methodological challenges

EE settlement is interested in investigating how different dwelling types and settlement patterns affect travel behaviour and, more specifically, travel mode choice and distances travelled. This section summarizes major issues raised by the literature reviewed, which should be considered when estimating these effects.

2.4.1 The difficulty of disentangling effects

To investigate the effects of the variables of interest (in this case dwelling types and settlement patterns), models must control for other factors which are also determinant for travel behaviour. This is true because the effects of all these explanatory factors interact and affect each other. For instance, it is important to control for residential location when investigating residential characteristics at the neighbourhood scale, as the location of a specific neighbourhood within the urban area may explain some of the characteristics of that neighbourhood (Næss, 2006). Otherwise, one could overlook the fact that what seems to be a direct effect of neighbourhood characteristics on travel behaviour may, in fact, be (at least partly) an indirect effect of location (Engebretsen et al., 2018).

Control variables may also vary depending on the travel purpose being investigated. For instance, in order to investigate the effects of residential location characteristics on commuting, it is important to account for the effects of workplace location characteristics, whereas for other travel related purposes (e.g. leisure), workplace location may have little or no effect on travel mode choice (unless these trips are executed in combination with commuting travel).

Generally, the more (relevant) variables are included in the model, the more variance in the outcome variable the model will explain. Studies which compare the variance explained by initial models and models that include additional explanatory variables illustrate this (e.g. Elldér, 2014; Cao et al., 2007; Vibe et al., 2005; Steg et al., 2001). However, the more variables are included in the model, the more challenging it will be to account for all type of direct, indirect, spurious and mediating effects. Pontes de Aquino & Timmermans (2010) argue that most of the studies that suggest evidence of the causal effect of the built environment on travel behaviour misuse the term "control" and do not distinguish between direct and indirect effects.

Even more challenging is to account for the interdependency of choices among households' members and other users of the transport system.

2.4.2 Self-selection

This aspect is related to the former described challenge (i.e. the difficulty of disentangling effects), but it deserves a dedicated section because it is a frequently discussed issue among researchers and practitioners. Self-selection occurs when a dweller selects their residence because the transport facilities offered in that residential area match their transport preferences. Pontes de Aquino & Timmermans (2010) argue that most of the studies that find correlations of residential area characteristics with travel behaviour do not account for self-selection and that such effects may therefore be misleading. People may not choose not to travel by car because they live in a residential area that is sufficiently dense and/or close to the city centre to offer good public transport standards and service facilities, but because they wanted to use public transport in the first place and that preference drove them to choose to live in that

of city within the country, employment level in the city (no. of jobs in the city per 1,000 inhabitants), land-use mix in the neighbourhood, locally available shopping and sport facilities, housing density, population density, and degree of urbanization.

area. Evidence of self-selection is reported by Hjorthol (2003), Cao et al. (2007) and Handy et al. (2005). This and further criticism have led to analyses which attempt to elucidate whether the characteristics of the residential area have a direct effect on travel related choices or are a mere reflection of dwellers transport preferences. Cao et al (2009) provides an overview of methods that allow for accounting for self-selection issues. These include direct questioning, statistical control, instrumental variables, sample selection, propensity score, joint discrete choice models, structural equations models, mutually dependent discrete choice models, and longitudinal designs. Cao et al (2009) conclude that longitudinal structural modelling approach is the most appropriate method because it allows for measuring attitudes, as well as for considering multiple directions of causality and measurement at multiple points in time.

As a result, some studies show that the explanatory power of residential area characteristics is reduced when models incorporate other factors in the regression analysis (Cao et al., 2007; Handy et al., 2005). Studies reviewed by Krizek (2003) show that attitudes better explain travel behaviour, or that the influence of urban form is reduced after controlling for attitudes. Cao et al. (2007) analyse cross-sectional data from households in eight neighbourhoods in Northern California and find that the effect of neighbourhood characteristics on car ownership is marginal compared to that of socio-economic and demographic characteristics, and that the effect disappears when the model incorporates individuals' neighbourhood preferences and travel attitudes, indicating that those initial found effects are primarily a result of self-selection. Their analysis of longitudinal data shows an effect of neighbourhood characteristics on car ownership – even after accounting for preferences and attitudes, but the researchers themselves acknowledge that those effects may be due to preferential and attitudinal changes which they assume constant (Cao et al., 2007). Similar limitations apply to results obtained by Krizek (2003). Analysis of longitudinal data from households relocating in a metropolitan area in Washington (USA) shows that increases in neighbourhood accessibility (while controlling for regional and workplace accessibilities and socio-demographic factors) have a negative effect on travelled distances (both generally and by car). However, Krizek (2003) himself acknowledges that the study does not account for attitudinal changes (which could eventually have driven those relocations).

However, other studies show that residential characteristics and urban structure play a key role even when models account for self-selection (Næss et al., 2017b; Strand et al., 2010; Cao et al., 2009). Longitudinal and cross-sectional analysis of data from Oslo and Stavanger conducted by Næss et al. (2017b) indicates that the effect of the residential location on travelled distances and mode choice (especially for commuting) is significant, even after accounting for socio-economic and demographic characteristics and preferences. Based on a review of empirical studies (38) addressing self-selection, Cao et al. (2009) conclude that the influence of the built environment on travel behaviour is statistically significant even when accounting for self-selection, although effect sizes vary depending on travel mode, trip purpose, the characteristics of the built environment being measured (local vs. regional), and population characteristics. Also, based on a literature review of Nordic and international studies as well as on a cross-case study (Oslo, Akershus), Strand et al. (2010) argue that density, accessibility, and diversity have an impact on both transport range and mode choice, even when controlling for self-selection issues, the built environment at the neighbourhood level, and cultural factors. Moreover, Næss (2012) and Engebretsen et al. (2018) argue that self-selection reinforces the importance of urban structure for travel-related decisions. Whether this influence is exerted directly or indirectly through residential choice does not change the fact that urban structure is an influential factor.

2.4.3 Correlations or causality?

This is also related to the issue of self-selection (but not only). For instance, urban form and characteristics may influence mode choice by defining the given travel possibilities in a specific neighbourhood or their relative attractiveness, but apparent significant effects of urban form and characteristics on travel behaviour may also only reflect individuals' attitudes and preferences (Krizek, 2003). According to Pontes de Aquino & Timmermans (2010) assumptions on causality are one of the main drawbacks of studies which suggest that there is evidence on the causal effects of the built environment on travel behaviour. According to them, travel behaviour is influenced by functions within urban forms and how well these fit life trajectories and not by the urban form themselves. Researchers investigating factors that explain travel behaviour make assumptions (normally based on previous literature) on the variables

included in the model and on the causal order. They decide which variables should be omitted and which are the cause and effect variables. These assumptions are not tested in regression analyses. We only test whether the independent/explanatory variables specified in the model show positive or negative effects on the dependent/output variables.

However, these assumptions may also be wrong and/or change over time and across sites. Positive relationships between having access to a car and the likelihood to travel could be, for instance, either way. If we assume that having access to a car comes first, we deduce that having a car contributes to travel more. However, the causal order of the relationship could also work the other way around (Vågane, 2000). A further example relevant to the scope of this project is the relationship between travel attitudes and residential location choices. Car ownership and travel attitudes may influence residential location choices, as well as residential location choices may influence car ownership and travel attitudes (Næss, 2012). Preferences do not always precede choices. Choices may also influence preferences based on learning experiences (Steg et al., 2001; Gärling & Young, 2001). If the assumptions about causal order are wrong, regression coefficients would reflect correlations between variables rather than cause-effect relationships. In-depth interviews and longitudinal studies can enhance models and contribute to a better understanding of causality. In-depth interviews can uncover rationales that underpin mechanisms behind travel choices while longitudinal studies can unveil causal order.

2.4.4 Data implications

It is important to be aware of the implications of employing different types of data (e.g. register vs. perceived; aggregated vs. individual) when interpreting results.

Register vs. perceived data. Most studies investigating the effects of contextual factors on travel behaviour employ register data describing residential and workplace location and distances; densities, land use mix, urban structures, and form on travel behaviour. However, perceptions greatly vary from individual to individual and they may exert great(er) influence on travel-related decisions than reality (Cao et al., 2007).

Aggregated vs. individual data. Pontes de Aquino & Timmermans (2010) argues that the combination into models of individual data (e.g. travel activity) and aggregated data (e.g. neighbourhood characteristics such as density) gives the impression that we have a greater sample than what we actually have (because several individuals actually share the same neighbourhood) and will, thus, underestimate the standard errors of the regression coefficients. Krizek (2003) also argues that data aggregation is often a drawback of studies assessing the effects of urban form on travel behaviour because it may lead to ecological fallacy (e.g. one assumes that summarized data, such as neighbourhood average density applies to each individual living in that neighbourhood); and often applies to artificial administrative zones that have little to do with reality (e.g. an individual may live in the same building as her neighbour but get assigned different neighbourhood densities, if the administrative boundary runs in such a manner that cuts that building into several zones). This challenge is less relevant for Norwegian studies, as these are usually based on very detailed data on e.g. density measured locally around the residence.

2.4.5 Contextual limitations and temporal changes

Studies that investigate the influence of local (and sometimes regional) contextual factors on travel behaviour must necessarily limit that context to a certain geographic area. Studies conducted across case areas (Engebretsen et al., 2018; Næss et al., 2017b; Næss et al., 2017a) show that effects are highly contextual dependant. Thus, generalizations are challenging. Moreover, there are further wider "contextual" factors driven by trends, markets and/or policies that may also influence travel behaviour. It can be challenging to investigate their combined effects with the explanatory dimensions presented in the previous section. Longitudinal studies can help to capture changes over time and provide knowledge to review/update models. For instance, a disinterest among younger generations for holding a driving license may increase the relative importance of travel preferences when choosing where to live (self-selection). Furthermore, policies promoting the use of specific transport modes and/or vehicles, and changes in the composition of local and regional economies (types of industry and services offered) may also interact with the explanatory variables reviewed and influence travel behaviour.

2.5 Conclusion

The literature reviewed indicates that residential location and characteristics influence travel choices. However, these interact with many other factors. Housing policy and residential planning may contribute to reduce car use and vehicles kilometres travelled, but further aspects need to be considered. Findings from Strand et al. (2010) suggest that land use planning should be seen in conjunction with other types of measures such as facilitation of public services and vehicle pricing. This document provides an overview of factors, which – according to the literature reviewed – should be considered when explaining travel behaviour and investigating the effects of dwelling types and residential patterns on travel mode choice and travelled distances. These factors can be grouped into three dimensions: socio-economic and demographic variables, attitudes and preferences, and contextual factors.

Analysis attempting to explain travel behaviour should control for socio-economic and demographic variables to minimize the extent that the effects of investigated factors (e.g. residential characteristics) are due to individuals and households' socio-economic and demographic characteristics. The main factors that should be considered are having access to car, income, education, occupation, age, gender, household size and structure, and travel purpose. Travel attitudes and residential preferences are investigated to a lesser extent, although they can help to exclude self-selection effects. There is also plenty of evidence of the effects of contextual factors on travel behaviour. These include residential and workplace location, land use mix, local and regional densities, parking availability and pricing, public transit standards, dwelling types, and urban and transport network forms. Moreover, future estimations of residents' energy need for transport must, if feasible, deal with the methodological challenges raised in section 2.4.

This review is neither a meta-evaluation nor is it complete. There may be a range of other factors that affect travel-related decisions (e.g. weather). For instance, it does not consider regional factors that go beyond the urban/metropolitan area, although research shows that regional factors influence changes in the labour market and service provision, which in turn affect distances travelled. Although differences in travel behaviour tend to be smaller across urban areas than within large urban areas, the regional function of urban areas (along with size and density) is also an important explanatory factor in a regional perspective because commuting travel distances may be influenced by the extent to which that urban area can supply jobs to its inhabitants and inhabitants of surrounding municipalities (Engebretsen & Christiansen, 2011), among other factors. Engebretsen & Vågane (2008) analyse national travel data, commute statistics and other register data as well as local surveys to show that regional expansion (due mainly to road construction and in part / part of the country the development of public transport, through intercity trains and express buses) has contributed to increased travel distances for both commuting and shopping trips (as well as to better access to jobs and the labour market). Furthermore, the study shows that the likelihood of commuting to a regional headquarters is decreasing at a distance. Also, Engebretsen (2006) examines commuting and shopping trips reported in the Norwegian Travel Survey and find that the share of jobs within the municipality and the degree of regional integration, along with business and workplaces localization and the development of transport infrastructure affect commuting travelled distances. Analysis conducted by Vågane (2000) also shows that the share of people who do not travel is higher in the most peripheral municipalities (i.e. municipalities with less than 5000 inhabitants), and that people living in municipalities surrounding the six largest Norwegian cities also have the largest daily travel distances.

In order to truly understand travel behaviour, research should also consider the interdependency of individual choices with those from other household's members and other users of the transport system; as well as how past choices and learning processes influence new choices and travel decisions (Gärling & Young, 2001).

Transport choices are taken in complex settings and the effect of each of the explanatory variables is probably different in each of these settings. Therefore, we have chosen not to focus on reviewing the precise effect size. Instead, we have simply summarized the factors that – according to previous empirical studies – influence travel behaviour and, thus, the energy embedded in transport generated by resi-

dents of different dwelling types and settings. In the next work packages (WP2), EE Settlement will empirically investigate the size of the influence of these factors using data from Norway.

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3 Housing and location preferences among households

3.1 Introduction

Between 2007 and 2017, the population of Norway increased 12.3 percent. In the five biggest cities, population increased even more, growing 18.1 percent.

Table 3.1
Norwegian population in 2017, and changes 2007–2017 (Source: Statistics Norway)

Population	Norway	5 biggest municipalities
Total population in 2017	5,258,317	1,357,776
Percent change 2007–2017	12.3	18.1
Composition of population increase 2007–2017		
- Birth surplus	33	48
- Net migration from abroad	67	57
- Net migration from rest of Norway	-	-5
Sum	100	100

For the country as a whole, net migration from abroad constituted two thirds of the population increase. Looking only at the five biggest municipalities, birth surplus constituted nearly half of the population increase. Net migration to these cities from the rest of Norway were negative in the period.

At an age of 40 half of the population in Norway live in the municipality where they grew up (Sørlie et.al., 2012). Two-thirds of these have never moved out of the municipality, and the last third is return movers. Among the second half of the population, one of ten moved against the mainstream, that is, out of city regions or from smaller city regions to periphery. One in three has moved in the opposite direction, and the rest have settled in a municipality at the same centrality level as the one they grew up in.

Migration from the rural areas to the city regions has contributed to increased centralisation in the past decades, as children are increasingly born and raised in urban areas. After 1990, the child population is more strongly represented inside the major city regions. If the child centralizing trend continues, this means that for every person who permanently moves to the centralized areas, the centralisation effect of each move will be strengthened (Sørlie et.al., 2012).

3.2 Mobility in Norway

Statistics Norway publishes data on mobility, both within and between municipalities, but series data are only available back to 2005. Figure 3.1 shows the variation of mobility rate with age for the year 2016, for mobility both with and between municipalities.

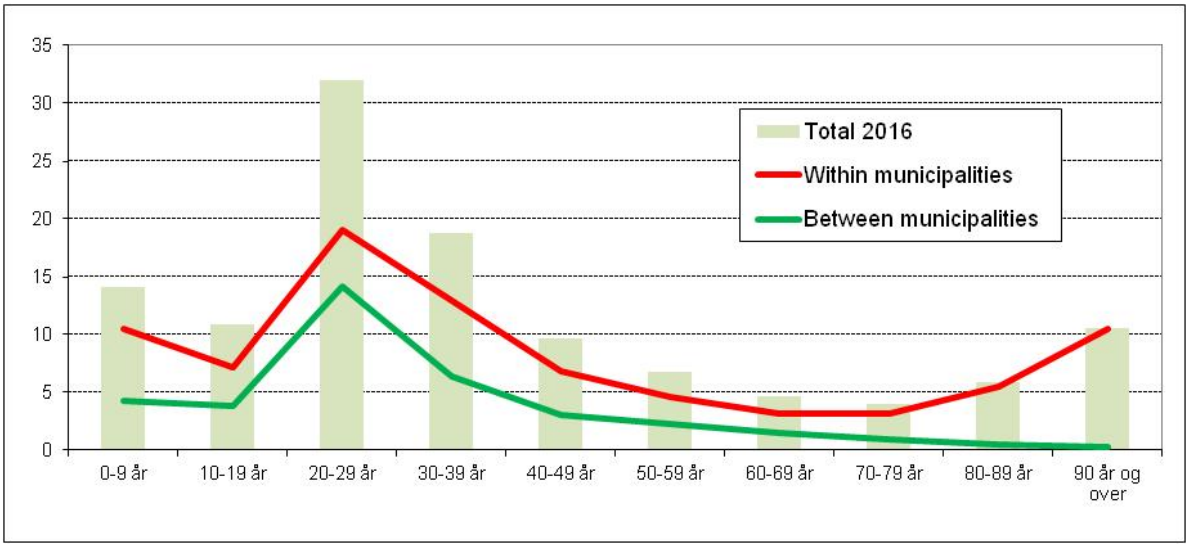

Figure 3.1
Yearly mobility rate after age group. Mobility within and between municipalities. 2016. Source: Migration statistic, Statistics Norway

Data from Statistic Norway show that nationwide, around 13 percent of the population changes address each year and about one third of these cross a municipal border. Except for the elderly, the age distribution is similar for moves within, and moves between, municipalities. Taking all moves together, the share is highest for the age group 20–29 years, in which more than 30 percent moved during 2016, and the share is lowest for the age group 70–79 years, with fewer than 4 percent. Among those 90 years or more, about 10 percent moved within the municipality during 2016 and almost none between municipalities. The moves in this age are often to a nursing home.

In contrast to short distance mobility, where housing is a main motive for moving, work, education, and family (as well as housing) are important motives when crossing a municipal border (Sørlie et.al., 2012). In urban areas three driving forces often shape the development pattern there; housing preferences, the business location pattern, and investment in public infrastructure. A challenge in these areas is to plan for the most sustainable development, with the least possible transport work.

Figure 3.2 shows the changes in the mobility rate for migration between municipalities for the period 2005–2016. The migration pattern is stable over the time period 2005–2016. During the financial crisis from 2008 there was a fall in the migration rate, especially in the age group 20–29. The centralisation of the population tends to increase faster during good economic times, rather than during bad times. There are two explanatory factors with opposite effects when the economy worsens. First, there are fewer job possibilities in the big cities, so fewer young people move there. Second, fewer households want to increase their dwelling space through migration from a big city to its surroundings, where the price per square meter is generally lower. Their housing plans are delayed until their perception of the economic outlook changes for the better. Still there was a net migration in all years in the period of the financial crisis, especially because of the high net immigration from former Eastern European countries, which have now become members of the EU. In contrast to most Europe during the financial crisis, the Norwegian unemployment rate was nearly unchanged.

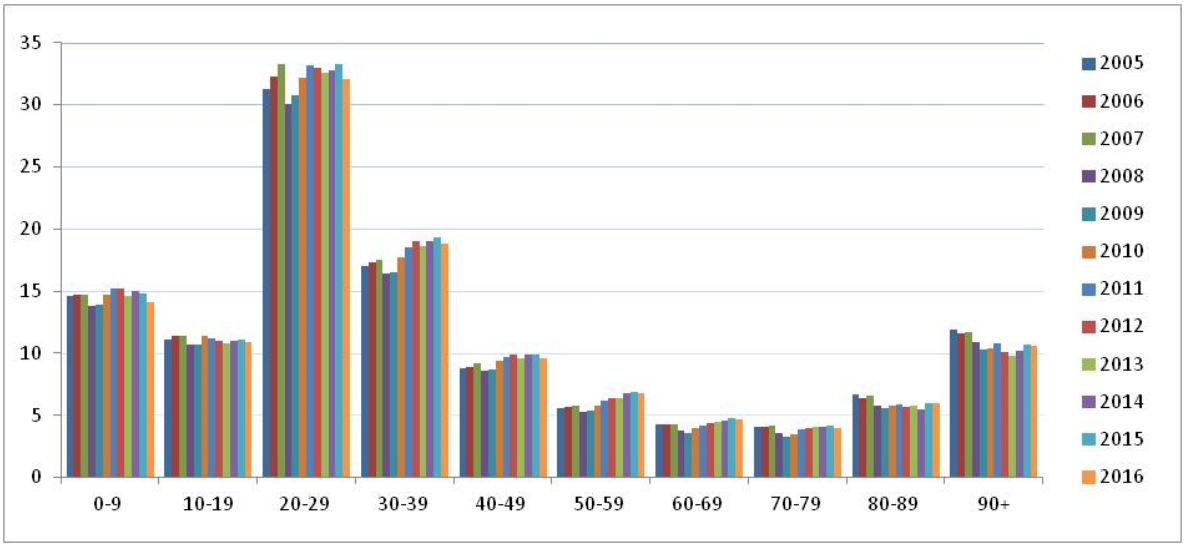

Figure 3.2
Yearly mobility rate after age group. Mobility between municipalities. 2005–2016. Source: Statistics Norway

One of the explanations for why families with children move from the big cities to the surrounding municipalities is to purchase more square meters for the same price. In figure 3.3 we show the variation in the Oslo and Akershus region.

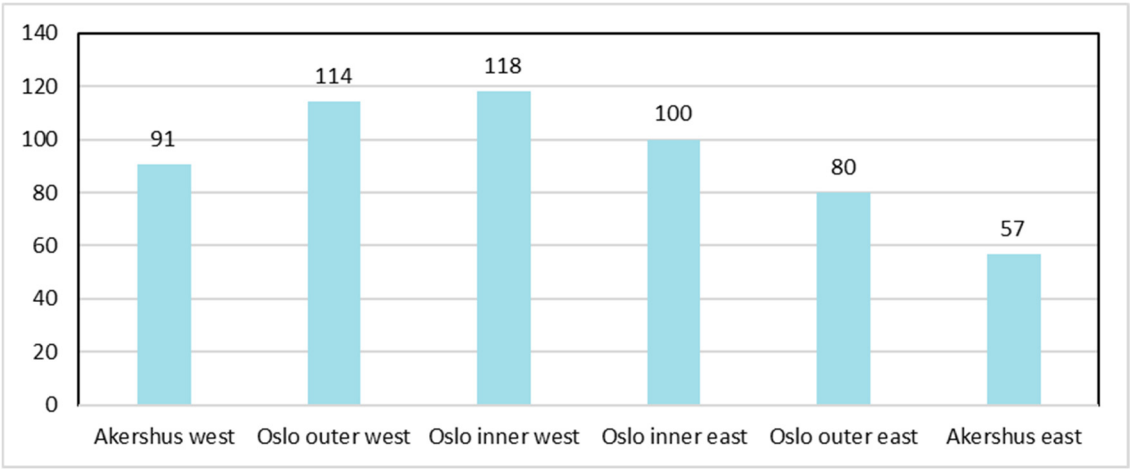

Figure 3.3
Relative house prices in the Oslo-Akershus region in 2014. NIBR, based on data from Statistics Norway. Oslo inner east = 100. Prices are controlled for size, construction year and house type.

Oslo inner west had the highest house price level in 2014, 18 percent higher than in Oslo inner east. The price level in Akershus east was 57 percent of the price level in Oslo inner east.

In a residential and labour market region (RL-region)[15] most of the jobs are in the centre of the region, where the supply of goods and services are highest (Gundersen and Juvkam, 2013). The area around this centre is densely built, and in growth periods the city will develop either by urban sprawl or through brownfield developments and densification. The relative house prices will be a result of greater shortage of land in the most central parts of the region and the size of the travel cost from the urban fringe to the

[15] Gundersen and Juvkam (2013) made an update of NIBR's classification of Norwegian municipalities into "Bo- og Arbeidsmarkedsregioner (BA-regioner)" roughly translated as "Residential and Labour market regions" (RL-region). Norway currently has 160 RL-regions. The division into RL-regions is intended to be a functional expression of the geographical correlation between household and working life while also serving as a geographical building block in analyses. RL-regions are based primarily on commuting figures and distance between centres.

centre. In a situation with spatial arbitrage a household will be indifferent between a central location without travel costs and a housing alternative outside the centre but with travel costs (DiPasquale and Wheaten, 1996). In growing urban areas, the densest floor space ratio will be in the centre, and more of the detached houses and row houses will be found in the surroundings of the big cities. Households which have preferences for such houses will then likely find their next home there, and possibly cross a municipality border to get it.

When travel costs and house prices are seen in connection, the housing market can be in equilibrium even if house prices are much higher in the centre than in the surroundings. A market in equilibrium will still have households moving from one submarket to another. The main explanation is that households go from one stage of a life course to another.

3.3 Knowledge status on residential mobility

In the literature on mobility there is a distinction between intra-urban and inter-urban mobility, where the latter is often considered migration or long-distance moves, often triggered by job-related or "human capital" reasons (Li and Tu, 2011).

Migration is often seen as a response to geographic disparities in economic opportunity (Gabriel et. al., 1993). According to standard economic theory the decision to migrate occurs only when the projected economic returns associated with migration – net of transaction costs – are positive. Labour mobility is seen as an important mechanism of relocating labour to the most productive use. The positive return can be separated between local economic conditions affecting potential income and local amenities that influence the quality of life. Relative house prices, with the highest prices in the most productive regions can work as a barrier for such moves.

The general explanation for moving between local labour markets - the decision to migrate occurs only when the projected economic returns associated with migration, net of transaction costs, are positive – can also be used when considering residential moves within a local labour market.

Theories of intra-urban mobility are rooted in sociology and geography disciplines, where the focus is on dissatisfaction with original location triggered by life cycle changes (Li and Tu, 2011). Economists have tried to model the decision-making process with a neo-classical, micro-economic approach of utility maximization on housing consumption mismatch, resulting from an unexpected economic or demographic shock. This approach also included a wealth effect, the effect of mortgage constraints and risk aspects connected to transactions in the owner-occupied sector (Li and Tu, 2011). Many studies stress the importance of seeing the demand for housing as a joint mobility-tenure decision. Tenure here refers to housing ownership status (e.g. renter, owner).

The increased utility resulting from moving to a new house, more in line with the resources and the composition of the households, must be greater than the transaction cost connected to the move. This line of economic thinking supposes that the expected future utility from moving must be greater than the transaction cost, before moving becomes an attractive option. Before a household will move there then must be a certain gap between actual and desired housing consumption (Weinberg, Friedman and Mayo, 1981). Since both resources and the composition of households change over time, several moves can be expected during a lifetime. Every move will have transaction costs and the number of moves over a life span will then be optimized. Recent movers will not necessarily be in equilibrium, understood as every move going to a dwelling which is in accordance with the households need at the time of the move. If the household expects to have (more) children soon, they can wait before moving to a house appropriate for the future composition of the household.

A household must choose several housing dimensions when moving: tenure, house type, and size, in addition to location. Location usually strongly correlates to house prices. For rich households there are two forces drawing in opposite directions. Rich households want larger homes and are attracted by lower housing prices in the suburbs. At the same time their opportunity cost of time influences commuting costs. Bruckner et al. (1999) assume that the ratio of commuting cost to dwelling area falls with income,

which leads to wealthy households being concentrated in the suburbs. He also shows that preferences for location vary with socio-economic variables. When a centre has strong amenity advantages over the suburbs, rich households are more likely to live in central locations. Amenities in the centre can then pull affluent households towards the centre. This model is used to explain why high-income residents in US urban areas tend to live in suburbs, and that these income groups tend to live more centrally in Europe, see also Flambard (2017).

Yates and Mackey (2006) discuss the sequences of three main dimensional choices of housing demand: tenure, type and location. Usually one assumes that the choices are taken in a certain sequence, first tenure, then dwelling type, and finally location, but they recommend a flexible specification of models for residential choice, since in practice some households deviate from the mentioned sequence.

Flambard (2017) finds that an increase in income, age, size of household, or housing cost to income ratio increases the probability of being an owner of a house in the suburbs. In some of the cities studied, amenities in the city centre make up for a less spacious dwelling and make household to a larger degree to prefer location in the inner city. In these cities, the coefficients for the explanatory variables were insignificant. Cities where most suburban inhabitants drive their car to work on free highways prefer to locate in suburbs. The authors recommend policymakers to be aware of the effect of better road accessibility on urban sprawl. An important conclusion for a sustainable development is also the importance of improving city centre amenities, compared to the suburbs.

Mulalic and von Ommeren (2017) show that with a doubling of income, the average household in Denmark will reduce the distance from home to workplace from 18 to 16 kilometres. In other words, the net effect of household income on distance to work is negative. The analysis also shows that the effect is higher for singles than for couples. They find that the effect is smaller or non-existent in bigger cities compared to smaller cities. The explanation could be higher house price differences between the centre and the suburbs in larger cities, and perhaps better public transportation.

A survey of moving motives among 6,000 people that moved in New Zealand in 2005 or 2006 revealed that many of the individuals that moved between local working markets reported social- or consumer-related motives, rather than work, as motives for moving (Morrison and Clark, 2011). The authors argued that people changing jobs had likely secured better salaries in the new location.

Gkartzios and Scott (2010) studied counter-urban movement in the greater Dublin area and found that the main motives for moving from urban to rural areas were living in a better, larger, and cheaper house, and that the area was more family-friendly. The area was also associated with a better quality of life, lower density, reduced noise, a slower pace of life, and less crime. The pull factors dominated in explaining the move; especially the social environment in rural areas, but also the physical environment and lower house prices.

Gkartzios and Scott (2010) point out that this migration pattern is associated with unsustainable patterns of spatial developments. Urban sprawl is developing; nearly 60 percent of counter-urban migration involves a move to a new property. The authors ask for planning interventions in urban areas that could better consider consumer preferences and satisfy these quality-of-life demands in urban areas.

Residential mobility or short distance moves are often triggered by imbalances between current dwelling area and desired space. Most of the households have less space than they desire, while some elderly have more space than they need. Behind these judgments of existing and desired dwelling area are changes in the personal economy, birth and changes in marital status (Clark and Huang, 2003). In addition, there could be some push and pull factors connected to the existing and future neighbourhoods. Many households report a desire to be a homeowner as an independent reason to move (Barlindhaug, 2003). House prices can be a limiting factor, but also an explaining factor behind moves within the same residence and labour market region (RL-region).

3.4 Motives of moving in Norway

Twenty percent of the municipalities in Norway have a population less than 1800 inhabitants, while 12 percent have a population of more than 20,000 inhabitants. A move across a municipality border can be done without changing job, but then other motives than work will be mentioned when respondents are asked about the reasons for a move. Gundersen and Juvkam (2013) made an update of NIBR's classification of Norwegian municipalities into RL-regions. To enable comparability over time, the criteria are relatively unchanged; though travel time considerations have been tightened in the update. The report also presents a newly developed centre structure based on urban settlements and municipalities, together with newly developed centrality classifications at the municipal and regional levels, which take the centre structure as their point of departure. The updated section consists of 160 RL-regions. The division into RL-regions is intended to be a functional expression of the geographical correlation between household and working life while also serving as a geographical building block in analyses. RL-regions are based primarily on commuting figures and distance between centres.

Households often want to move within a RL-region to increase their dwelling area in square meters without having to pay the highest house prices. Such adjustments will often result in a move from the most central part of a RL-region to cheaper areas in the outskirts of the region. They could keep their job, but then will have higher daily travel costs. The possibilities for daily travel from the outer part of a RL-region to the most central part, where most of the jobs are located, will be highest in the most populated regions. The demographic foundation for offering high frequent public transport will be stronger there. In this way, the surroundings of the biggest cities will be attractive for location both of new labour force moving from less productive areas, and for households who move from the centre of the region to the surroundings to get more dwelling area for the money, but who will keep their job in the centre of the region. We therefore find housing as a main motive among those moving from a big city to its surroundings, crossing a municipality border when moving.

A considerable share of the migration to the biggest cities in Norway consists of young single persons seeking a job or getting higher education. After some years, many of them start working there and want to establish a family. Before their children start school, they find a more permanent residence, based on strong preferences for single-family or semi-detached houses. In the centre and the outer parts of the big cities, these houses are few and expensive. Therefore, many move to nearby municipalities to find more affordable houses, where they are able to increase their dwelling area.

In a situation with strong centralisation in Norway the ministry of local government and regional development wanted to know more about the motives behind both moving and non-moving. Within the "Survey of Living- and migration motives 2008", NIBR focused on migration and non-migration between municipalities during a seven-year period (1999–2006) (see Sørlie et al., 2012).

The motives for moving or staying in the survey are based on subjective reasoning. Many of the factors people respond to are of individual matters. Jobs are important regardless of whether people justify their moving decision with work or not. In a residential and labour market region, the same can be valid for access to housing.

Birth cohorts, born every seven year, in the age range from 21 to 70 years were interviewed. Those who had moved in the period were asked about the motives for the last move over a municipal boundary, and those who had not moved were asked about the motives for staying in the municipality for the least seven years. Here we only report answers from the respondents who had moved in the period.

24 regions were constructed, based on centrality and geography. Using "The Statistics Norway Register of migrations 1964-2006", the respondents could be divided into three moving categories, dependent on where they lived at the time of the survey and at age 15; return movers to the municipality where they lived at age 15, internal movers within one of the 24 regions and regional movers. The last group were movers who lived in another region than at age 15. All migration from abroad was excluded from the survey. In the analyses the type of mover was used as an independent variable.

The survey was structured within six main themes: employment/work, housing, place/environment, family, health and education. The first four of these contain 93 percent of the responses. Education and health were minor motives. There were 1524 movers in the sample who answered some or all of the questions, both a telephone interview and a postal questionnaire, both of these implemented by Statistics Norway in cooperation with NIBR. The response rate was around 50 percent, taking into consideration incorrect information in the register data about moving or not moving. In the analyses data is weighed, so that they represent all movers crossing a municipality border in the period (the last move if several moves in the period 1999–2005).

3.4.1 Reported motives for moving

Those who reported a move in the survey were first asked to answer seven questions about which motives were in their mind when they moved. Housing could then be mentioned as one of several motives. All together housing was mentioned by 44 percent. In moves within RL-regions, 65 percent mentioned housing as the only, or as one of several motives. In table 3.2 below, we report the distribution of the *most important* motives for moving.

In migration between municipalities, family is mentioned as the most important motive for moving, with a share of 27%. Housing is the second most important, mentioned by 24% of respondents. In migration between RL-regions, family and work are the most important motives. Compared to moves within a RL region where 41% mention housing as the most important motive, only 13% of those moving between RL-regions mention housing.

Table 3.2
The most important motive for moving. All migration between municipalities after moves within RL-regions and between RL-regions. Expressed in percent.

Most important motive	Moves between RL-regions	Moves within RL-regions	Moves between municipalities
Health	**2**	**2**	**2**
Place	**14**	**17**	**15**
Housing	**13**	**41**	**24**
Family	**30**	**23**	**27**
Education	**6**	**1**	**4**
Work	**25**	**8**	**18**
Several motives[1)]	**10**	**8**	**9**
Sum	**100**	**100**	**100**
% of N = 1,371	**58%**	**42%**	**100%**

[1)] Cannot determine the most important motive

In urban RL-regions the supply of jobs is relatively plentiful. Motives other than work are mentioned more often in such regions. Another explanation is that in urban regions with better communication it is easier to move without changing job. Looking at motives for those moving within the five urban RL-regions, we find that work only count 4% and housing 46%.

The data cannot tell if a migrant changed job when moving. Only a few of the respondents, those who answered that work was one motive for moving, were asked if they after moving was in the same job as before moving. Our data can by the way tell if the respondents were in the same industry (3 number code) before and after the move. It is possible that some of those with the same industry code before and after the move have continued in the same industry but changed job location.

Table 3.3
Share who were in the same industry before and after the move. Percent of the group.

Location after migration	Moves between RL-regions	Moves within RL-regions	Moves between municipalities
All migrants			
Big city	**46**	**57**	**49**
Big city surroundings	**56**	**74**	**70**
Rest of the country	**55**	**66**	**58**
All	**53**	**69**	**59**
Only migrants with a job before and after the move			
Big city	**60**	**72**	**64**
Big city surroundings	**73**	**85**	**82**
Rest of the country	**69**	**79**	**72**
All	**67**	**81**	**73**
All migrants			
Big city	**227**	**106**	**333**
Big city surroundings	**94**	**300**	**394**
Rest of the country	**513**	**193**	**706**
All	**834**	**599**	**1433**
Only migrants with a job before and after the move			
Big city	**172**	**86**	**258**
Big city surroundings	**73**	**263**	**335**
Rest of the country	**410**	**160**	**570**
All	**655**	**508**	**1163**

Of all migrants, 59% remained in the same industry before and after the move. Among the others, some for example can have moved for education and some for retirement. If we concentrate on the respondents who had a job before and after the move, 73% were in the same industry before and after the move. The share is highest for moves within a RL-region and especially those who moves to the city surroundings within a RL-region has a high percent of respondents who were in the same industry before and after the move (85%).

Those who mentioned housing as a motive for moving were asked for under motives connected to moving from the existing dwelling.

Table 3.4
Under motives for moving *from* the existing dwelling.[1)] All migration between municipalities after moves within RL-regions and between RL-regions. Percent

Housing sub-motives	Moves between RL-regions	Moves within RL-regions	Moves between municipalities
The dwelling was too small	**34**	**42**	**39**
The dwelling was too big	**5**	**6**	**6**
Wrong house type	**10**	**14**	**13**
Wanted to be a home-owner	**34**	**27**	**30**
Other	**17**	**10**	**13**
Sum	**100**	**100**	**100**
N =	**143**	**229**	**372**

[1)] Several motives could be mentioned. 18% mentioned 2 or 3 motives. All mentioned motives are computed in percent of 100. 12% of the respondents were excluded because they only mentioned place as a reason for moving from the existing dwelling.

Most of the households moved because the existing dwelling was too small. The share was higher in moves within RL-regions. The other main reason for moving was a wish to be a homeowner, 30% mentioned this.

Table 3.5 shows the actual tenure forms before and after the move. We have also computed the share of movers who increased housing consumption, measured in number of rooms before and after the move.

Table 3.5
Tenure form and share with increasing housing consumption in number of rooms before and after moving

From\To	Big cities	Big city surroundings	Rural	All
Share who is owner before and after the move				
Big cities	29	68	47	55
Big city surroundings	49	57	56	54
Rural	28	42	37	36
All	35	60	42	46
Share moving from renting to owning				
Big cities	39	23	34	29
Big city surroundings	25	32	22	27
Rural	46	34	37	38
All	37	27	34	33
Share increasing housing consumption				
Big cities	51	71	68	67
Big city surroundings	32	46	40	40
Rural	40	34	42	41
All	40	57	48	49

Of those who moved from big cities to the surroundings 68% were homeowners before and after the move. For all migrants the share was 46%. One third of all migrants changed tenure from renting to owning when moving. This share is highest among migrants from rural areas moving to the big cities. The share increasing their housing consumption was highest in moves from big cities to its surroundings or to the rest of the country.

In the next section we will contrast the findings to the result of the survey of living conditions from 2004 and 2007. In these surveys all respondents who had moved were asked about their motives for moving. We limit the results to those who had moved the last three years before the survey was implemented.

Table 3.6
Motives behind the last move

	2004	2007
Work or education	**19**	**30**
Housing conditions	**27**	**26**
Personal reasons	**47**	**38**
Other	**6**	**6**
Sum	**100**	**100**

Source: Survey of living conditions 2004 and 2007. Moves during the last three years

Surprisingly work and education had a considerable increase from 2004 to 2007 in charge of personal reasons. Housing as a motive was unchanged in the period and on the same level as in our survey from 2008. Since the survey of living conditions also includes moves within municipalities one should believe housing as a motive should be higher. The survey of living conditions also asks for sub-motives in addition to main motives. Those who mentioned housing as the main motive had the following distribution on under motives in 2004 and 2007.

Table 3.7
Distribution of sub-motives – housing.

	2004	2007
A smaller dwelling	**3**	**1**
A larger dwelling	**37**	**32**
Lower housing expenses	**4**	**3**
More modern dwelling	**9**	**10**
More suitable for children	**6**	**6**
Less traffic, noise and pollution	**3**	**4**
More central location	**6**	**4**
Be homeowner	**17**	**20**
Had to move from rental accommodation	**5**	**10**
Other reasons	**9**	**9**
Sum	**100**	**100**

Source: Survey of living conditions 2004 and 2007. Moves during the last three years

The sub-motives among those having housing as the main moving motive have about the same distribution as in the survey of living- and migration motives from 2008. Moving to a larger dwelling and to be a home owner are the main reasons for moving.

3.4.2 Housing as a moving motive in different migration streams

In this section, we referee from a logistic analysis on the variation in mentioning housing as the main motive for moving (Barlindhaug, 2013). First, we give a description of the size of the different migration streams and the share in each stream with housing as the most important moving motive. Big cities consist of the cities Oslo, Bergen, Stavanger, Trondheim and Kristiansand. The surroundings of these cities are defined as the municipalities in the RL-region where these cities belong.

Table 3.8
Size of migration streams. Percent of total.

From\To	Big cities	Big city surroundings	Rural	Sum
Big cities	**6**	**13**	**11**	**30**
Big city surroundings	**8**	**11**	**8**	**27**
Rural	**10**	**5**	**28**	**43**
Sum	**23**	**29**	**48**	**100**

Of all moves between municipality borders, 23% move to one of the big cities, 29% to these cities' surroundings and 48% to one of the municipalities in the rest of the country. The smallest streams we find in migration between the big cities, and from the rest of the country to the big city surroundings. Most of the migration is migration between municipalities in the rest of the country.

Table 3.9
Share in each migration stream with housing as the main moving motive.

From\To	Big cities	Big city surroundings	Rural	Sum
Big cities	**9**	**51**	**17**	**31**
Big city surroundings	**29**	**44**	**28**	**35**
Rural	**10**	**15**	**22**	**18**
Sum	**16**	**43**	**22**	**27**

Housing as the main motive for moving is most often mentioned by those moving from the big cities to the surroundings, and by people moving between municipalities in the surroundings.[16] Housing is also mentioned frequently by respondents moving from big city surroundings to big cities and to the rest of the country.

In the analyses of the variation in the frequency who mention housing as the main motive we will bring in other independent variables than moving directions. We are expecting that couples with small children will move out of the big cities to get more room space for a lower price and that they also want to bring

[16] The data show that almost none move from one big city's surroundings to another big city's surroundings.

up their children in a more child friendly environment. We then bring in age, being a couple before moving and having children before moving as independent variables in the analyses. Gender is also included.

The respondents are divided into three moving categories, dependent on where they lived at the time of the survey and at age 15; return movers to the municipality where they lived at age 15, internal movers within one of the 24 regions and regional movers. The last group is movers who lived in another region than at age 15. This variable is used in the analyses.

A regional mover moved between one of the 24 regions, based on centrality and geography, and ended in a region where the respondent did not live at age 15. The 24 regions were used to draw a stratified sample in the survey. Internal movers moved within one of these 24 regions while a back mover moved to the municipality where the respondent lived at age 15. The variable internal mover was slightly significant.

The migration streams were divided into several directions. The reference direction was moves from a RL-region in the rest of the country to another RL-region in the rest of the country. Two migration streams gave a lower probability for mentioning housing as the main motive for moving; namely migration between big cities and migration from big city surroundings to big cities. None of these variables were significant.

At last we have split up some of the migration streams in a way that moves to and from Oslo and Oslo's surroundings could be separated from moves within other urban regions. In addition, we have separated the migration stream between municipalities in the rest of the country in two streams. This we did by separating moves within RL-regions in the rest of the country with other moves.

Table 3.10
Logistic regression. Dependent variable: Housing as the most important motive for moving.

	BI		Change in probability
Constant	-2,2293		
Age 40–70 years (reference age < 40 years)	-0,3898	*	-5
Not in couple before/after moving (reference in couple)	-0,7954	***	-10
Not children before moving (reference having children)	-0,4381	**	-6
Reference: A regional mover			
A back mover	0,2418		4
Internal mover	-0,4617	*	-6
Reference: From rest of the country to rest of the country, between RL-regions			
From big city to big city	-0,3592		-5
From 4 big cities to surroundings	1,4429	***	31
From Oslo to surroundings	2,2917	***	51
From big city to rest of the country	0,3016		5
From surroundings to big city	1,220	***	25
From surroundings to surroundings	1,655	***	36
From surroundings to rest of the country	1,070	***	22
From rest of the country to big city	-0,122		-2
From rest of the country to surroundings	0,793	*	15
From rest of the country to rest of the country, inside a RL-region	1,575	***	34
Gender (reference man)	0,073		1

* p<0.05; ** p<0.01; *** p<0.001
Reference person: Regional mover under 40 years with partner with children, who moved from the rest of the country to the rest of the country between a RL-region.

In the table we present the size of the coefficients and how much the probability for mentioning housing as the main moving motive changes when varying the dummy variables from 0 to 1 or opposite. When doing this we have to define a reference person, because in logistic regressions these effects will vary with how the reference person is defined.

We find that younger people living in couples, and having children before the move, have higher probability for reporting housing as the main motive for moving than people aged 40 or more, those who are not living in couples and those who do not have children.

We find the highest effect on housing motives in migration streams from Oslo to Oslo's surroundings, increasing the probability of mentioning housing as the main motive with 51 percent points in contrast to the reference moving direction. Also moves within the surroundings of the big cities, moves from the other big cities than Oslo to the surroundings and all other moves from the surroundings considerably increased the probability. Also moves within RL-regions in the rest of the country increased the probability of mentioning housing as the main motive for moving.

Being an internal mover reduced the probability for mentioning housing as the main motive for moving. Other motives were more important for this group of movers, for example place and family.

The analyses show that especially young couples with children moving from the big cities to the suburban municipalities mention housing as the most important motive for moving between municipalities. When we hold this pattern up against what we know about relative house prices in these regions and what is often mentioned as under-motives among those who have housing as the main motive, the results indicate that these households move out of the big cities to the cheaper surroundings to achieve

larger living space. Even though many report "becoming a home owner" as a motive for moving, most of these young families with children already are home owners before moving. Many families with children also think such areas are the most appropriate for bringing up children.

3.4.3 Market failures and implications

Brueckner (2000) mentions several types of market failures that can stimulate urban sprawl in contrast to more compact development. First mentioned is the failure to take account of the social value of open space when land is converted to urban use. Another failure is on the part of individual commuters to take account of the social costs of congestion created by use of the road network. A third failure arises from the failure of the real estate developers to take account of all public infrastructure costs generated from their projects. The first mentioned failure can be corrected for by charging a development tax. A solution for the second failure is to introduce a congestion toll. A way to correct for the third failure is to introduce a system for impact fees, in Norway regulated in the Planning and Building Act[17] as development agreements. Such fees reduce developers' willingness to pay for agricultural land and thus the interest for urban sprawl development. Another solution to reduce urban sprawl is to set a boundary for development around the city, but Brueckner (2000) does not recommend this. Another problem connected to urban sprawl is actions of different municipalities covering the actual urban area.

The Government put strong pressure on local authorities for a coordinated land and transport plan to minimize transport work from home to job. This can be done by building more densely with increased density around public transport stations. The preference among young families with children for increased dwelling area in the outskirts of the urban area are in opposition to the sustainable development goals of the Government. As Gkartzios and Scott (2010) pointed out, this migration pattern is associated with unsustainable patterns of spatial developments.

A partial solution can be found in changed mobility patterns among middle aged and older households. Some of these households have already moved from a detached house to a smaller apartment close to public transport, shopping centres, and public and private services. The houses these households leave behind are filled up by young households with children moving from the inner city to the suburban areas. But this is probably not enough to cover the demand from the young families with children, taking into consideration the future high expected population increase, most of it coming from work immigration, but also a demand coming from a large group of young people growing up in urban areas.

3.5 Conclusion

In theory, the house price structure of metropolitan housing markets follows a pattern in which central prices gets an addition reflecting saved travel costs from the city border and into the centre (DiPasquale and Wheaten, 1996). A representative household will then be indifferent between settling in affordable housing far from the city centre, with daily travel costs, and settling centrally without these travel costs, paying more for the same dwelling. High central land prices contribute to a desire for high land utilization and typical high-priced multifamily housing, while on the city border there will be less land exploitation and a housing supply mostly consisting of detached houses. Preferences for house type and location changes over the course of a person's life. Both Norwegian and international literature find that families with children generally prefer to move out of the inner city into less expensive housing, where the extra costs for increasing dwelling area are lower. Current housing and land policy for various reasons focus on compact development, where sale prices are high. This gives an offer not directed to families with children. Older household are encouraged to move into these developments to free up their existing houses for families with children, but many elderlies find that the price of the new residence is considerably higher than the selling price for their existing residence. During many years, stable low annual moving rates can be observed for the age group 60–79 years. Continuing this trend in urban areas with a growing number of households with children, can lead to a mismatch between the supply and demand of housing types. Can this be resolved through better planning of new homes in the inner city? We want to map the current mobility pattern in selected metropolitan regions in more detail and through surveys reveal various household's housing and location preferences. Are they changing over time?

[17] https://www.regjeringen.no/en/dokumenter/planning-building-act/id570450/

What planning interventions could better consider consumer preferences and satisfy these quality-of-life demands in urban areas?

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4 Concluding remarks

The study provides an overview of factors (focusing on socio-economic and demographic variables, attitudes and preferences and contextual factors) that should be considered when explaining travel behaviour and investigating the effects of dwelling types and residential patterns on travel mode choice and travelled distances. The results show that main factors that are considered to evaluate the travel behaviour are socio-economic and demographic variables such as "having access to car", income, education, occupation, age, gender, households' size and structure and travel purpose. Travel attitudes and residential preferences are investigated to a lesser extent, whilst there is plenty of evidence of the effects of contextual factors on travel behaviour. Empirical investigation of the size of the influence of these factors using data from Norway is suggested in further work in the project.

The evaluation from preferences for house type and location changes shows a trade-off between settling in larger housing farther from the city centre, with daily commuting costs, and settling centrally in a smaller or more expensive dwelling, but without the commuting costs. One approach to solving this mismatch is encouraging elderly households to move into more compact developments to free up their larger dwellings for families with children, but often the price of the new residence is considerably higher than the selling price of their existing residence. This leads to low stable annual moving rate of elderly in urban areas and to a mismatch between housing supply and demand. In further work the current mobility pattern in selected metropolitan regions will be evaluated in more detail to evaluate potential solutions that could enable better planning in different settlements.

EMBODIED ENERGY, COSTS AND TRAFFIC IN DIFFERENT SETTLEMENT PATTERNS

TRAVEL BEHAVIOUR, HOUSING AND LOCATION PREFERENCES

This report provides a state-of-the-art review of existing relevant studies concerning factors influencing residents' energy needs for transport, and housing and location preferences among households.

The report provides an overview of factors that should be considered when explaining travel behaviour and investigating the effects of dwelling types and residential patterns on travel mode choice and travelled distances.

The evaluation from preferences for house type and location changes investigates the mobility patterns and the trade-off between settling in larger housing farther from the city centre and settling centrally in a smaller or more expensive dwelling.

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