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Land Use and Travel Behavior in Small Cities

Arealbruk og reiseatferd i små byer

Fitwi Wolday

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Fitwi Wolday

Norwegian University of Life Sciences
Department of Urban and Regional Planning
Faculty of Landscape and Society

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Summary

Research on the relationship between land-use and travel behavior has been at the forefront of finding solutions to the ever-growing challenges of energy demand and urban pollution associated with transportation. However, much of the research has been focused on medium-to-large cities. Since relationships between built environment and travel behavior are geographically contextualized, the extent of influence of built environment on travel is contingent on geographic context. As a result, the effect of policy-relevant built environment factors are likely to vary between cities of different sizes.

Small cities accommodate a sizable share of national populations (e.g. 28 % in Norway). Small city residents are largely car dependent, often with long driving distances and low shares of active travel. A serious effort attempting to promote sustainable mobility cannot do so without properly understanding what shapes travel behavior in small cities at both local and regional scale. To contribute in filling the knowledge gap and inform small-city planners on their quest for sustainable mobility, this thesis focuses on the relationship between built environment and travel behavior in a small-city context.

The overarching research question of the thesis is: which built environment attributes and transport strategies can best serve the goal of sustainable mobility in a small city context? This main question was addressed by formulating a number of researchable questions addressed in the four articles included in the thesis.

The four articles fall under three main research themes. The aim of the first research theme is to investigate the significance of travel attitude as a source of bias in land-use and transportation research. Its purpose in the thesis is to inform the succeeding two research themes on how to model travel attitudes in travel behavior research. The second research theme investigates the influence of neighborhood, local (city scale) and regional built environment factors on car driving distance in a small city context. The third research theme focuses on so-called active transport (walking and biking) and investigates the relationship between built environment and active transport at the neighborhood as well as city scale in small cities.

The role of attitudes towards active transport is given special attention in the last theme. In modeling active transport, travel attitude is included not as a control variable but as a variable of prime interest due to its direct effect on motivation to active transport. The modeling framework is inspired by ecological models and informed by lessons from the first research theme.

Survey data from three small cities in the southeastern part of Norway are used to answer the research questions. In addition, the small-cities' data is supplemented by data from Oslo metropolitan area, which is specifically used to address the issue of travel-induced residential self-selection. With the exception of the first article, where mixed-methods approach (combining quantitative and qualitative methods) was used, the thesis employed mainly quantitative methods of analysis in investigating the effect of the built environment on motorized and non-motorized travel behavior.

The main conclusions of the study underscore that regional context is important to understand how and to what extent residential location affects travel behavior in a small city context. In a city such as Kongsvinger, where regional pull-factors from a nearby higher-order city is weaker, living close to the center of the small city significantly reduces total car driving distance. In cities with proximity to a higher-order city, the influence of residential distance from the city center on driving distance is weaker and likely mediated by transit commutes due to higher propensity among commuters working in the larger city to commute by transit if they live close to the center of the small town. Among the demographic and socio-economic characteristics, gender has an influence in all three cities, with men tending to drive longer distances than women do. The influence of income and employment are strongest in the cities that are most strongly integrated into the labor market of the Oslo region.

Regarding the relationship between built environment and active transport behavior in small cities, attitude towards active travel is found to exert the strongest influence on the propensity to bike/walk. Neighbourhood-level accessibility to facilities is also important but its influence varies by trip purpose (facility type). For trips to grocery stores, availability of such stores in the neighborhood is highly influential whereas for more specialized stores and facilities (center facilities), concentration of facilities close to the city center is more strongly associated with a high frequency of walk/bike trips. Topography also influences the likelihood of traveling by active modes, irrespective of destination type, for example by reducing the frequency of walking and biking trips among residents of hilly neighborhoods.

Three main recommendations with implications for urban planning policies can be drawn from this thesis. First, planners should avoid measures that lead to sprawling of center facilities, for example, shopping centers at city fringes. Second, since grocery stores accessible at a neighborhood scale increase the propensity of active travel, new residential areas should be developed in such a way that the population base for neighborhood facilities such as grocery stores is sufficiently high. Third, the analysis also reveals that attitude towards active travel exerts strong influence on people's tendency to travel by non-motorized modes. Therefore, awareness campaigns to sway individual and community attitudes coupled, for example, with incentives to the adoption of electric bikes in order to reduce the level of exertion associated with topographical contours may likely boost walk/bike frequency.

Sammendrag

Forskningen om forholdet mellom arealbruk og reiseatferd har lenge vært en viktig del av innsatsen for å finne løsninger på de stadig voksende utfordringene om energibehov og luftforurensing i byer knyttet til transport. Mye av forskningen har imidlertid vært fokusert på store og mellomstore byer. Siden forholdet mellom bystruktur og reiseatferd avhenger av den geografiske konteksten, er det grunn til å tro at bystrukturelle faktorers innvirkning på folks reiseatferd vil variere mellom byer av forskjellige størrelser.

I mange europeiske land bor en betydelig andel av befolkningen i små byer (eksempelvis 28% i Norge). Beboerne i små byer er i stor grad bilavhengige, ofte med lang kjørelengde og lav andel av ikke-motoriserte reiser. Byplanlegging for å fremme bærekraftig mobilitet kan derfor neppe nå målene uten grundig forståelse av hvordan bystrukturen i små byer påvirker reiseatferd. Denne avhandlingen fokuserer på forholdet mellom bystruktur og reiseatferd i småbyer for å forbedre kunnskapsgrunnlaget for bærekraftig areal- og transportplanlegging i små byer.

Avhandlingens overordnede forskningsspørsmål dreier seg om hvilke bystrukturelle faktorer og byplanstrategier som kan best tjene bærekraftig mobilitet i små byer. Dette hovedtemaet er belyst ved å formulere en rekke konkrete spørsmål som besvares i de fire artiklene som inngår i avhandlingen.

De fire artiklene faller forskningsmessig under tre hovedtemaer. Målet med det første forskningstemaet er å undersøke betydningen av transportrelaterte holdninger for sammenhengen mellom arealbruk og transportatferd. Funnene i denne artikkelen informerer de påfølgende to forskningstemaene om hvordan man best mulig kan ta høyde for transportholdninger i undersøkelser av forholdet mellom bystruktur og reiseatferd. Det andre forskningstemaet undersøker virkningen av bystruktur på nabolags-, lokalt (byskala) og regionalt nivå på kjørelengde i små byer. Det tredje forskningstemaet fokuserer på ikke-motorisert transport, og undersøker hvilke egenskaper ved bystrukturen i nabolaget og i byen forøvrig som påvirker ikke-motorisert transportadferd i små byer.

I den sistnevnte undersøkelsen får individets holdning til ikke-motorisert transport spesiell oppmerksomhet. Transportholdninger er tatt med i de empiriske analysemodellene for aktiv transport, ikke som en kontrollvariabel men som en viktig forklaringsvariabel. Dette i motsetning til den tradisjonelle praksisen i undersøkelser av forholdet mellom bystruktur og reiseatferd, der transportholdninger antas å være en mulig feilkilde som det eventuelt må kontrolleres for. Valget av analysemodell er inspirert av økologiske modeller og funnene fra det første forskningstemaet.

Avhandlingens primære datakilde er en spørreundersøkelse i tre små byer (Kongsvinger, Jessheim og Drøbak) i Sørøst-Norge i desember 2015. I tillegg er småbydataene supplert med data fra Oslo byregion. Dataene fra Oslo byregion er benyttet til å studere betydningen av transportholdninger i beboernes valg av bo-områder. Med unntak av den første artikkelen, hvor en blanding av kvantitativ og kvalitativ forskningsmetode ble brukt, bygger avhandlingen i hovedsak på kvantitative analysemetoder.

Studiens hovedkonklusjoner understreker at den regionale konteksten betyr mye for hvordan og i hvilken grad boliglokalisering påvirker reiseatferd i små byer. I en by som Kongsvinger, hvor regional innflytelse fra andre større byområder (Oslo) er moderat, bidrar boliglokalisering nær sentrum til redusert kjørelengde med bil. I småbyer som ligger nær en storby, er innflytelsen av boligens avstand til småbyens sentrum på kjørelengden med bil svakere og består sannsynligvis først og fremst i at de som pendler ut av byen oftere velger kollektiv transport hvis de bor nær sentrum. Når det gjelder demografiske og sosioøkonomiske egenskaper, har menn konsekvent høyere tilbøyelighet enn kvinner til å kjøre langt, mens inntekt og sysselsetting har sterkest virkning i de byene som er sterkest integrert i Osloregionens arbeidsmarked.

Når det gjelder forholdet mellom bystruktur og aktiv transport i småbyer, viser avhandlingen at folks holdning til ikke-motorisert transport har størst betydning for folks bruk av sykkel og gange som transportmidler. Tilgjengelighet til fasiliteter på nabolagsnivå er også viktig, men betydningen av dette varierer etter type fasilitet (reiseformål). For dagligvarebutikker er nærhet til boligen viktig for å fremme gange og sykling. For mer spesialiserte butikker og fasiliteter (senterfasiliteter) er beliggenhet i sentrum av byen gunstigere for å fremme høy hyppighet av gange og sykling. I tillegg kan terrengforholdene påvirke sannsynligheten for å reise med ikke-motoriserte transportmidler (for eksempel bidrar kuperte nabolag til mindre sykling og gange).

Tre hovedanbefalinger for byplanlegging i små byer kan gis ut fra denne studien. For det første bør planleggere unngå utbyggingstiltak (eksempelvis kjøpesentre ved utkanten av små byer) som fører til spredning av sentrumsfasiliteter. For det andre, siden tilgjengelighet til dagligvarebutikker i nabolaget øker tilbøyeligheten for aktiv transport, bør nye boligområder planlegges på en slik måte at det blir stort nok kundegrunnlag for viktige nabolagsfasiliteter som dagligvarebutikker. For det tredje viser analysen at folks holdning til ikke-motorisert transport har stor innflytelse på om de velger å bruke slike transportformer. Derfor kan bevisstgjøringskampanjer for å styrke en positiv holdning til ikke-motorisert transport blant individer og på samfunnsplan, trolig øke gange-/ sykkelbruken. Incentiver, for eksempel til bruk av elektriske sykler for å redusere anstrengelsesnivået i motbakker, kan bidra til det samme.

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1. Introduction

The aim of this research endeavor is to investigate the relationship between urban structure and travel behavior in the context of small cities. Land-use and transport interaction is one of the intensely researched areas in the urban planning field during the last three decades. However, despite the immense wealth of literature, the focus has predominantly been on larger cities, save a few and sporadic contributions (Handy et al. 2010; Holden 2001; Hu et al. 2018; Næss & Jensen 2004; Skjeggedal et al. 2003). Even within the limited coverage, the size difference among the cities labeled as small cities is immense. A small city in Chinese context, for example Changting (Hu et al. 2018), would qualify for a medium to large city in the European context.

Transportation to facilities and activity participation are simultaneously anchored in time and space. This spatio-temporal constraint is susceptible to scale differences, i.e. differences in urban size and scale of analysis (neighborhood, local and regional contexts) (Dijst 1999; Hong et al. 2014; Kwan & Weber 2008; Kwan 2012b; Milakis et al. 2015; Nielsen & Skov-Petersen 2018; Zhang & Xie 2015; Zhang et al. 2012). As a result, research findings from larger urban areas may not be transferable to smaller cities.

A sizable share of the Norwegian population live in small towns and hamlets. Data on settlement sizes for 2015 from Statistics Norway show that 44.3 percent of the Norwegian population live in settlements[1] with population size of 30 000 or less. While the proportion living in small cities with inhabitants ranging between 3 000 and 30 000 is about 28% of the total Norwegian population (Statistics Norway 2015). At the European scale, the proportion of the European population in small cities of corresponding sizes is also comparable.

Although many small cities are likely to be influenced by the regional context for their economic and cultural life, most of them are centers of their municipalities, which are often administratively independent of the regionally dominant higher-order centers. In all practical terms, these cities are essentially independent planning units that are often not integrated into the urban planning schemes of the major city.

Research consistently depicts sub-urban residents as car dependent characterized by longer travel distances and lower share of sustainable modes of mobility (Cervero 1989; Crane & Crepeau 1998; Næss 2006). Many small cities also qualify for such characterizations. As Christaller (1966) noted in his central

[1] Statistics Norway defines settlements as localities with continuous built up area with 200 or more inhabitants. Localities with less than 200 inhabitants are therefore not included in the figures.

place theory, many small cities surround a larger urban area. Residents of these smaller cities may then tend to travel to the higher order regional center for work, cultural and commercial activities. Setting aside the influence from differences in urban hierarchy, small cities also lack the population base required for the supply of certain services such as efficient and frequent public transport and therefore have to depend predominantly on private cars.

Private car use is a major source of environmental pollution in general and urban air pollution in particular. Road traffic is the third largest emitter of greenhouse gas (GHG) in Norway, accounting for a fifth of all emissions in the economy and car use for personal transport carries a disproportionate share of these emissions. Norwegian data[2] on modal share of passenger transport puts the share of persons traveling by private car at 77% which is equivalent to 82% of all passenger kilometers for the years 2000 through 2014 (Statistics Norway 2016). Passenger cars accounted for 54 percent of road traffic emissions in 2014[3]. Perhaps equally dire, If not more serious, is the adverse effect of car use (for personal transport) in urban air quality and the adverse health effects associated with that. The WHO report on health effects of transport-related air pollution for Europe estimates tailpipe emissions of particulate matter from road transport to account for up to 30% in urban areas (Krzyżanowski et al. 2005). The same report also claims road transport to be the main contributor to nitrogen dioxide and benzene emissions in cities, and is the major reason for noncompliance with current European Union limit values for these pollutants. In addition, road traffic is a significant contributor to marine microplastics-pollution. According to Norwegian Environment Agency estimates, over half (55%) of the microplastics that end up in the sea come from tire wear and tear while driving (Sundt et al. 2014).

The proportion of residents who live in small cities and their mobility out-look (car dependence, long travel distance, low share of active travel, etc.) on the one hand and the skewed focus on larger cities on the other, make this research a worthwhile undertaking. A serious effort attempting to make inroads on sustainable mobility[4] cannot do so without properly understanding what shapes travel behavior in small cities at both local and regional scale.

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[2] Statistics Norway (http://www.ssb.no). Greenhouse gases, by energy product, pollutant, source (activity), contents and time. Visited September 19, 2016. The data includes all emission from the Norwegian economic activity within the Norwegian territory. Does not include international maritime and air transport.

[3] Ibid.

[4] Sustainable mobility, as used here, adheres to the EU's definition as one that enables individuals and societies to satisfy their needs for access to activity areas in complete safety, in a way that is compatible with the health of humankind and ecosystems, and with equity within and between generations. Sustainable mobility has to also be

This thesis sheds light on the research objective by first addressing a methodological issue related to travel-induced residential self-selection, followed by three articles that directly address how built environment attributes influence small city residents' travel choices.

The first article, that is, the methodological work critically examines the role of transport related residential preferences in residential location choice. The significance and implication of travel-induced residential self-selection in land-use and travel behavior research is also discussed here. The issue of travel induced residential self-selection bisects through the succeeding three articles. The methodological section is thus intended to reduce methodological ambiguity in the thesis and guide towards appropriate model specification in answering the research questions.

The second article investigates how the distribution of residences relative to the city center relates to car driving distance in small city context. Distance from the city center is the consistent and robust built environment attribute influencing travel behavior such as car driving distance (Ewing & Cervero 2010; Næss & Jensen 2004; Næss 2006; Næss 2011b; Næss et al. 2017; Stevens 2017; Zegras 2010; Zhou & Kockelman 2008). Also, in terms of effect sizes, residential distance to the city center has the highest magnitude (Ewing & Cervero 2010; Stevens 2017). However, these findings are predominantly from large cities. The studies included in the two most recent meta-analyses by Ewing and Cervero (2010) and Stevens (2017) focused exclusively on medium to large cities. Does influence of residential distance from the city center on car driving distance then extend also to the small cities? And, how resilient is it to regional influence and to variation in the small city's center structure[5]?

The third article builds on the research question raised in the second article and addresses the effect of neighborhood and city-scale built environmental characteristics on active transport. The inherent characteristics of being small, i.e. small population size, is a limiting factor in providing efficient public transportation. However, many small cities have a monocentric city structure with the city center (commercial, administrative and cultural center) in the middle. The small city size combined with the monocentric urban configuration creates an urban environment where its main functions are reachable by active modes (walking/biking). Questions addressed under this section include: how do differences in

affordable that offers choice of transport mode and limits emissions and waste within the planet's ability to absorb them (European Union, 2001).

[5] A small city's center structure refers to the physical form of the city center and relates to whether the city has a unified single center, diffused and spread-out center or multiple centers at spatially distinct locations. The idea of city center structure corresponds to the distinction of metropolitan regions between monocentric and polycentric metropolitan urban structures.

small cities' center structures and the distribution of facilities affect active travel magnitudes? Which factors increase the propensity for non-work trips by active modes? This section will also reflect on whether the premise for and reward (gains in terms of sustainable mobility) from densification is strong in small cities as it is in larger cities?

Lastly, the fourth article examines factors characterizing individuals with positive attitude towards active transport but who tend to travel less by active modes. The motivation to commit oneself to travel actively is an important component of the travel behavioral outcome. The significance of motivation is even more pronounced in active travel decisions than for travel by motorized modes (Cao et al. 2009c; Handy 1996; Handy 2015) partly due to the physical exertion involved. The question addressed here is, which factors hinder individuals with highly positive attitudes towards travel by active modes from realizing their active transport potential?

The rest of the thesis is organized in seven sections as follows. The next section presents the theoretical foundations related to the research work covered in this thesis. Section three covers the issue of causality in the land-use and transportation nexus. The ontological persuasion inspiring this research in explaining the basis for causation is discussed under this section. Data and methods are presented in section four, followed by short summaries of each article in section five. Section six covers the thesis' synthesizing section, which elaborates the research finding and potential contributions to research and practice. The final section presents the individual articles with appendix appearing in the end.

2. Theoretical frame

2.1. Travel demand

Individuals participate in various activities to satisfy their physiological, psychological, social and economic needs. Human activities are organized in specialized facilities that fit to the specific purpose such as home for residence, schools for learning, hospitals for health services and workplaces for jobs, each of which distributed in space (Wegener 2004). The demand for travel arises, primarily, from the desire to bridge the spatial gap that separates these facilities.

Understanding how we travel (and refining the techniques of modeling it) has been central to how transportation systems are supplied and alternatives are evaluated in project appraisals. There have been two dominant approaches in modeling travel demand with contrasting and far-reaching consequence in transportation and land-use planning. The oldest, and still widely in use, is the trip-based approach. The second approach relates to the activity-based approach. With congestion and transport-generated pollution as a growing problem, demand management objectives became policy concerns for transportation planners. Therefore, since the 1970s activity-based approach gained traction as a behaviorally prudent and policy responsive approach in transportation research.

Be it in the trip-based or activity-based conceptualization of travel, transportation is understood (implicitly or explicitly) as purely instrumental activity that is demanded to counter the spatial gap between activity locations. This section will discuss the dominant conceptualizations of the act of travel and discuss implications to land-use and transportation planning. Recent nuances to the dominant perceptions of travel are mentioned by the end of the section.

2.1.1. Trip-based approach in transportation research

Trip-based demand modeling is one of the most widely used demand models (and still widely in use in infrastructural appraisals). Transport generation and allocation (demand forecasting) between origin and destination using trip-based models is performed in a sequence of four steps, namely, trip generation, trip distribution, mode choice and trip allocation. Trip generation stage refers to the estimation of the amount of traffic/trips generated by or attracted to a given traffic analysis zone. In the second step, trip distribution, trip destinations are determined to create the origin-destination matrix of trips. The share of trips carried by each mode are determined in step three while step four assigns the modes into the available routes connecting origin and destination of the trips. With information generated from the four-step sequential demand forecasting model, the final evaluation of whether investment in transportation infrastructure is worthwhile or not is decided by a decision criterion such as benefit-cost-ratio assessed through cost-benefit analysis. In cost-benefit analysis, the benefit or economic value of time saved due to, for example, road improvement is weighed up against the financial, environmental and other costs (in monetary terms).

Traditional four-step models focus on trips as a unit of analysis with little regard for how the trips are scheduled and the interdependence between them in time and space (Bhat & Koppelman 1999; Hanson 1980). The behavioral detachment of trip-based models in travel modeling made them less responsive in the design and evaluation of effective demand management policies in addressing transportation-related negative influences such as congestion and pollution.

2.1.2. Activity-based approach in transportation research

Activity-based travel modeling approach emerged as an antidote to the shortcomings of trip-based models. The conceptual appeal of this approach originates from the realization that the need and desire to participate in activities is more basic than the travel that some of these participations may entail (Bhat & Koppelman 1999). The approach is, therefore, person/traveler-centered rather than trip-centered. The emphasis on activity participation and interconnectedness or sequence of activity behavior per unit of time (a day or a week for example) gives better behavioral fidelity and policy sensitivity (Bhat & Koppelman 1999; Shan et al. 2013).

Activity-based transportation research is firmly anchored in time geography, inspired by the works of Hägerstrand (1970) and Chapin (1971), among others. Hägerstrand, in his seminal work "what about people in regional science" emphasized the spatio-temporal fixity of activity participation. Human activities are distributed in time and space. Using his famous space-time prism concept, he elaborated the interdependencies between sequences of activities and the constraints that bind or mediate them.

In addition to spatial fixity of facilities, people's decision to participate in activities is also influenced by temporal fixity imposed on human activities. Facilities such as schools, shops, workplaces, etc. are open within certain intervals of a 24-hour daily loop, and some activities can only be carried out at a certain point in time during the day. This requires individuals/households to schedule their activities in a manner that is spatially reachable and temporally attainable, essentially trading time for space. Using more time, from a time budget limited by the length of the day, to reach a distant facility overrides the possibility of visiting some other facility.

Hägerstrand identifies three constraints that characterize the nature of trade-off between time and space. Capability constraints limit individuls' activities through their own physical capabilities or resource endowments. Capability constraints include maintenance activities (physiologcal needs such as eating and sleeping that require time and space) and availability of mobility resources that, somewhat, expand the spatial reach of an individual given a temporally fixed interval. Coupling constraints define when, where and for how long an individual has to join others for shared activities such as meeting, work, etc. Authority constraints refer to restrictions imposed over particular space-time domains. Domains refer here to a space-time entity within which things or events are under the controll of a certain individual or group. A gated community or a member only club can make participation difficult while a public square cannot.

Not all activities do, however, carry the same importance; some are more restrictive in terms of the space-time flexibility than others are (Chapin 1971; Cullen & Godson 1975; Hägerstrand 1970; Ås 1978). Hägerstrand (1970) distinguised between two groups of activities, fixed activities and flexible activities. Fixed activities are those activities that cannot easily be rescheduled (e.g. work, meetings) while flexible activities[6] can be easily rescheduled (e.g. shopping and recreation). Cullen and Godson (1975) argued that spatial and temporal constraints identified by Hägerstrand display varying degrees of rigidity. They indicated that temporal constraints are more rigid than spatial constraints and that the rigidity of temporal constraints is closely related to type of activity (with more temporal rigidity associated with work-related activities compared to leisure activities). Along the same line of argument, Vilhelmson (1999) Identified four categories of activities depending on the flexibility/rigidity of activities on a space-time continuum. The four ranges of activities include fixed in time and space, fixed in time but flexible in space, flexible in time but fixed in space and flexible in time and space. Furthermore, Vilhelmson (1999) labeled activities that are fixed in time as required activities while those that are flexible in timeas optional activities irrespective of the spatial fixity.

The fixed-flexible (obligatory-discretionary) dichotomy between activities has an important implication to how activities are scheduled. Fixed activities act as space-time anchors in activity scheduling because they condition the timing and location of other activities (Hägerstrand 1970; Miller 2016). Physiological needs (such as sleeping/maintenance) and subsistence activities (such as work) take precedence in the activity hierarchy and dictate how other activities are organized. As a result, individuals and households schedule their daily routines around the obligatory activities and fit the discretionary activities into the basic pattern outlined by the obligatory activities (Jones et al, 1983).

2.1.3. The concept of derived travel demand and generalized travel cost (GTC)

Time cost makes up a lion's share of the generalized travel cost (GTC). Accordingly, timesaving is often the largest component reflecting the benefit or gain from transport infrastructure improvement because time spent on travel is entirely viewed as a cost in transportation planning.

The demand for travel is generally understood as a derived demand; derived from the desire to participate in spatially and temporally distributed activities (Jones, 1983, Kitamura, 1988, Fox 1995). While it is subtly implied in the trip-based demand forecasting models, the concept of derived demand is

[6] Fixed activities are also referred as obligatory activities whereas flexible activities are referred as discretionary activities. Although classification of activities between the two categories is somewhat arbitrary, they have strong resemblance in usage ((Cullen & Godson 1975; Vilhelmson 1999; Ås 1978))

fundamental to activity-based conceptualization of transportation. The underlying supposition being that travel is undertaken solely for utilitarian purposes in order to access spatially scattered facilities. By extension, travel has no intrinsic (autotelic) utility other than what is derived from activity participation at destinations. This understanding has been central in transport demand forecasting and in the valuation of time saving in infrastructure investment appraisals. To that end, all time spent on travel is considered as a cost that has to, by definition, be minimized in utility maximization.

However, recent advances in research (Cao et al. 2009b; Mokhtarian & Salomon 2001; Mokhtarian et al. 2015; Redmond & Mokhtarian 2001; Salomon & Mokhtarian 1998; Steg et al. 2001) appear to challenge or at least modify the conventional wisdom by distinguishing between utilitarian and autotelic travel. Joy-riding, recreational walking/jogging/cycling, horseback riding, etc. are among examples where travel is demanded for its own sake, i.e. travel is the primary objective while destination is ancillary/arbitrary.

Autotelic travel (undirected travel as it is also known) is a small proportion of the overall travel and it is largely related to travel for leisure activity (Mokhtarian & Salomon 2001). Still, undirected travel is also likely to be an integral part of the directed (utilitarian) travel, for example, when a person visits a distant destination even when local alternatives of the same quality are available. Another example would be when a person chooses to reside at a 15-minute walk from her work rather than 5-minute walk because of positive experiences along the way or because she wants a buffer between activity realms (Ory & Mokhtarian 2005; Salomon & Mokhtarian 1998).

Undirected travel embedded in the utilitarian, although subtle and difficult to detect, may have important implications for travel demand management and transportation planning. Transportation planning under the assumption that all travel is extrinsic would definitely overestimate the return to transport investment. Travel demand measures designed under the same assumption would also underachieve, as the intrinsic value of travel may lead to excess travel[7]. Excess travel in itself is not an issue, it is how the excess travel is carried out (or what mode one uses) that is important. As Cao et al. (2009b) note, society benefits if individuals satisfied their autotelic travel by using active modes rather than by driving. Although undirected travel is believed to be largely influenced by attitudes, residential characteristics such as non-cul-de-sac street pattern and aesthetic quality encourage active travel (Cao

[7]Excess travel, as used here, is understood in line with the notion of derived demand and refers to all travel that is performed beyond what is instrumentally desirable.

et al. 2009b). The extent to which the demand for excess travel by motorized modes is absorbed (substituted) by the demand for local travel by active modes is, however, unclear.

2.1.4. Induced travel demand

The dawn of the car as a main mobility vehicle in the 20th century and the euphoria of increased accessibility afforded by the car fueled a continued construction of freeways (Boarnet & Crane 2001). This led to distortions in relative prices between different transport modes which again culminated in the form of long term unfavorable land-use changes. The cumulative result of the expansion, which became apparent starting the late 1950's, was rapidly sprawling urban regions, deteriorating air quality in urban areas and persistent congestion. The very objective of the 'predict and provide' approach to solving congestion perpetuated the severity of the problem (Crozet 2012; Ladd 2012; Noland & Lem 2002; Næss et al. 2014).

The transport related problems can be tied partly to the understanding of what constitutes the cost of travel (the generalized cost of travel). When the travel time component of the generalized cost of travel mainly reflects the opportunity cost of the traveler, it undervalues the true cost borne by the society. This systematically biases infrastructure investments in favor of car mobility instead of public transit. Again, the high accessibility by car combined with lower generalized travel cost borne by the individual attracts latent demand. Latent demand refers to the additional travel generated due to trips shifted in time, route and destination or induced vehicle travel due to shifts from other modes, longer trips and new vehicle trips. The lower cost generates more traffic by inducing those who were driving shorter distance to drive longer or those who were not driving to start driving. Furthermore, the lower relative cost of driving vis-à-vis transit-use will likely move people from transit to the road (Ladd 2012; Litman 2017). The cumulative effect is not only congestion in designated routes but also an absolute increase in vehicle kilometers traveled (VKT). The absolute increase in vehicle kilometers because of shifts from other modes, longer trips and new vehicle trips is referred to as induced travel (Hills 1996) and constitutes a major sustainability challenge.

2.2. Land-use and transport interaction

Transportation is primarily desired as a derived activity (although the intrinsic value of travel is recognized as explained above) in order to reach spatially separated facilities. The distribution of facilities in different land-uses in space necessitates transportation to facilitate human activities, intertwining land-use patterns and transportation systems with causal loops running both ways.

Traditionally, the relationship between land-use and transports has not been put to good (sustainability oriented) use. Mobility between facilities was largely believed to be best served through higher accessibility by motorized transport, predominantly personal vehicles (Boarnet & Crane 2001; Crozet 2012; Ladd 2012; Litman 2017). The focus of transport planners was to predict anticipated future traffic growth and meet the demand by expanding the infrastructure.

The expansive transport infrastructure and the high accessibility afforded by car led to dispersed and inefficient land-uses, which asserted the car as the main mobility vehicle and cultivated car dependence. Eventually, the mounting negative effects on the environment, health, urban quality of life and inefficiency associated with congestion led scholars and practitioners to rethink the "predict and provide" paradigm in transportation supply (Boarnet & Crane 2001; Crozet 2012). The last three decades have seen a concerted effort to arrest transport related negative consequences by focusing on proximity between facilities rather than providing accessibility to facilities through increased mobility.

The literature on land-use and transportation planning identifies a handful of land-use factors with a potential to influence travel behavior (mode choice, travel distance, etc.), which planners can utilize to steer transportation demand towards sustainable mobility. The dominant and recurrent ones among them are destination accessibility, land-use mixing (diversity), density (population/housing density, job density), neighborhood design, distance to transit, and travel demand management. The six built environment attributes are often referred to, in the literature, as the 6-Ds (Ewing & Cervero 2010) and are generic names for a set of several individual urban form attributes. The following sub-sections elaborate on each of the above-mentioned six built environment variables.

Spatial factors generally and built environment variables specifically are highly interrelated. Often, hosts of built environment features have to be aligned for land-use policies to deliver in terms of sustainable mobility. Some built environment attributes amplify/strengthen the effect of other built environment factors. In other circumstances, the causal tendencies of influential built environment factors may not be triggered unless other complimentary attributes are concurrently put in place. For example, high density and diverse land use pattern may not necessarily reduce driving unless efficient public transport service is put in place and travel demand management schemes such as access to parking are addressed. Higher density (population, job or/and housing) has the tendency to decrease average trip length and therefore travel time. This however depends in part on the extent to which density stimulates land-use mixing and efficient public transport provision, which again depends on the spatial scale at which densities occur. High density in a smaller city, for example, would not be as effective in influencing mode shift as in a larger city. Even between small cities the effectiveness of density and land-use mixing is likely to vary depending on the regional context within which the cities are imbedded (Wolday 2018a).

2.2.1. Destination accessibility

In the simplest term, utilitarian transportation is about facilitating access between spatially separate origins and destinations of a trip at an acceptable generalized travel cost (time, money, effort). Accessibility is defined in various ways leading to different methods to compute and operationalize it (van Wee et al. 2013). The definition adhered to in this thesis follows Dalvi and Martin (1976) where accessibility is defined as the ease with which any land-use activity can be reached from a location using a particular transport system. Fitting to this definition, the potential accessibility measure is adopted and a neighborhood accessibility indicator is calculated using the gravity based measure as proposed by Harris (2001).

The variety of accessibility measures also differ in their geographic scale: some are neighborhood level while others have city/regional reach. This thesis distinguishes between neighborhood accessibility, local accessibility, and regional accessibility because the spatial connotation of accessibility has important implications for travel decisions and thereby transportation and land-use planning policy.

Neighborhood accessibility refers to the potential of accessing destinations of interest by non-motorized modes (mainly walking) from one's place of residence. The meaning of neighborhood is a fluid concept. The spatial extent (boundary) of neighborhood varies depending on whether it is defined subjectively by the resident or based on revealed preferences about walkable distances to points of interest (Guo & Bhat 2007; Huie 2001; Jenks & Dempsey 2007). Since the focus of the thesis is on the intersection between built environment and travel, I opt for the mode-based accessibility definition (with neighborhood defined as the area within a given walking distance). Neighborhood is hence defined as the area within a half mile (805 meters) radius of the residence. Still, the limit of what is considered an appropriate walking distance for utilitarian purposes is debatable. However, many researchers set the limit at either a half-mile or one kilometer distance from trip origins (Millward et al. 2013; Perry 1929; Scheiner 2010; Zhang & Xie 2015). It is also common, among researchers, to use second best measures of neighborhood unit such as traffic analysis zones (TAZ), census tracts, census blocks, etc. However, the second best measures are largely imposed on researchers because of their wide use as statistical units in register based (secondary) data.

Residential distance from the city center or distance to the CBD, as it is also referred to, is often used a measure of regional accessibility. When the spatial scale investigated is a large city or a metropolitan region, distance to the city center can be an appropriate measure of regional accessibility. However, when the geographic scale of the city studied is small or medium sized, distance from the center of a small city is likely to be distinct from that of the regionally influential city center in its influence on travel decisions. In such situation, both the local and the regional centers are not mutually exclusive but mostly complementary (Milakis et al. 2015), especially from a sustainability perspective. Local accessibility will likely influence local travel by active modes as well as regional travel mode choice, e.g. regional job commutes by public transport (Wolday 2018b). Therefore, a distinction between local and regional accessibility is important to distinguish between implications of distance from the CBD at different geographic scales. In the present thesis, local accessibility is defined as residential distance from the center of the local city (i.e. small city). Regional accessibility, on the other hand, is defined as the distance between the city centers of local city and the nearest higher order city.

Residential location, as an important component of destination accessibility, is the most frequently investigated facility in travel studies, because it is where daily life is planned, travel scheduled, family life organized and not least the origin and ultimate destination of most of daily travel activities. Likewise, the city center, by providing the highest concentration of facilities in the urban space, establishes itself, presumably, as a primary destination of local trips. Residential distance from the city center, by bringing together the two important aspects of travel activity (the origin and destination), becomes an important construct in understanding the effect of built environment on travel behavior.

Sustainability oriented land-use planning recommendations and legislations (Norway's Governmet 2014) often focus on densification in central areas of a city. However, this goal may be challenged from two sides. First, land value in already developed areas near the city center is often costly and redevelopment is even costlier. In small cities, the economic gain from land-use development outside the built-up area may be considerable, from an individual agent's perspective, leading to leapfrog type development. New developments outside the built up area need not be far from the city center as small cities have a short radius to begin with. Second, although the building and planning act sets national guidelines (Norway's Governmet 2014), the planning units are municipalities and the planning legislation allows for adaptability to local conditions. This caveat combined with the competition among small cities to attract new residents and investment (Steffansen 2017) can put pressure to expand outwards prior to utilizing centrally located plots. Leapfrog type developments outstretch the small city, reduces density, weaken the city center and adversely influences sustainable mobility.

Residential distance from the city center has been an important and consistently robust representation of the influence of built environment on travel behavior in metropolitan regions (Cao et al. 2017; Ewing & Cervero 2010; Næss 2006; Næss 2011b; Næss et al. 2017; Zegras 2010; Zhou & Kockelman 2008). Decentralization of cities has been shown to lead to greater car use and reduced transit ridership (Cervero & Wu 1997; Schwanen et al. 2001), reduced active travel (Schwanen et al. 2001) and higher energy use and longer driving distances (Næss, P. & Sandberg, S. 1996; Næss et al. 1996). Conversely, cities with predominantly monocentric metropolitan structure were found to have higher transit use, less driving, reduced auto-ownership and reduced driving distance by car (Cao et al, forthcoming). Having these findings from larger cities as a backdrop, this thesis embarked on the question: can we claim similar gains from densification around small-city centers as in larger cities?

2.2.2. Density

Ever since Newman and Kenworthy (1989) published their seminal work on the effect of density on energy consumption for transportation purposes, density has been at the center of land-use planning to influence transportation towards sustainable mobility. Dense neighborhoods create the necessary condition for the establishment of commercial facilities thereby fostering mixed pattern of land-uses, which brings origins and destinations of travel closer together. Again, proximity creates the potential for higher non-motorized travel for local trips and higher transit ridership (Næss et al. 1995; Wolday 2018a). Higher density also facilitates public transport ridership by enabling to create frequent and accessible public transport services.

The effectiveness of density in increasing public transport ridership is, nonetheless, largely dependent on the geographic scale at which densities occur. In smaller cities, the small size limits the extent of land-use mixing and public transport provision.

2.2.3. Land-use mixing/diversity

Land use mixing refers to the diversity in land-use categories in a given location. Land use patterns that allow for diversity of facilities are often reported to have the potential to reduce motorized transport volumes through mode shifts and shorter trips. Having a diverse set of facilities such as residences, shops, schools etc. closer to each other reduces the distance separating these different facilities and therefore the distance individuals have to cover when navigating between different facilities for activity participation.

Land-use mixing is often used in a manner that is less spatially anchored. Discussions on land-use diversity often sidestep the important question of where in the urban space can diversity be operationalized. For example, when researchers claim that diversity reduces transport volumes, does that mean diversity everywhere in the urban space? Does this then advocate polycentric urban structures? Besides, diversity of which facilities is likely to lead to reduction in transport volumes?

As these set of questions indicate, diversity can subtly imply decentralization unless specifically addressed as not to mean so. The literature on diversity is not specifically unambiguous on what diversity entails and the geographic scale at which it is likely to influence travel behavior. The immense literature in the field produced during the last two decades has settled, by now, that residents in the central area of cities drive less, travel more by public transport and have higher rates of non-motorized travel. Diversity as a planning tool should therefore be seen in light of the broader urban scale. A handful of studies indicated that decentralization reduces travel distance (Gordon et al. 1989; Gordon et al. 1991; Gordon & Lee 2015; Levinson & Kumar 1997). More nuanced studies, however, reported results that differ by type of trades (for e.g. blue collar vs white collar). Decentralized metropolitan structure tended to lead to higher average travel distance for highly skilled workers whereas those with less skilled jobs and laborers tended to reduce their travel distances (Crane & Chatman 2003; Grunfelder & Nielsen 2012; Næss 2007a).

Historically, land-use mixing as a remedy for reducing car driving volumes was proposed following the sub-urbanization of jobs to many single-use job centers in the suburbs in the 1980s that can only be reached by car and the cross-commuting that ensued between urban and sub-urban destinations (Cervero 1984; Cervero 1986; Cervero 1989; Orski 1985). Cervero (1989) describes the land-use development trajectory of the time as follows:

> *"The way suburban workplaces are being designed, it could be argued, bears some of the blame for worsening congestion. In particular, the emergence of many suburban job centers that have a single dominant use, usually offices, could be inducing many employees to drive their own cars to work. These single-use office centers stand in marked contrast to traditional downtowns, most of which feature a rich variety of offices, shops, restaurants, banks, and other activities intermingled amongst one another. While downtown workers can easily walk to a restaurant or*

a merchandise store during lunch, those who work in many campus-style office parks are almost stranded in the midday if they don't drive their own car to work."

Land-use mixing, as proposed in those days, was not anchored to the metropolitan scale in terms of transportation infrastructure, residential location and job opportunities. It was rather a solution to locally patch off, a sustainability wise, detrimental regional land-use pattern. Whether such patch-works strengthen or weaken the overall car dependence is up for debate. But, if such measures further weaken the attractiveness of the central city area, and lead to the decentralization of the metropolitan regions in to small local centers, its contribution in reducing car dependence and driving volumes is likely to be limited (Næss 2011a; Næss et al. 2017). Apart from circumventing single-use land-use patterns that are already in place, how can planners operationalize mixed-use in planning practice?

Job housing balance is one aspect of the diversity indicators. Since daily commutes account for a high share of total daily travel distance, being able to work closer to home would definitely reduce transport volume. For this to work, the tendency for residence-work co-location should be strong. Nonetheless, the likelihood for co-location between work place and residence is weak (Hickman & Banister 2015; Næss, P. & Sandberg, S. L. 1996; Næss 2006; Næss 2007a). For one, the reason people choose their place of residence does not necessarily mirror the type of occupation they want to pursue nor is it strongly associated with their wish to live closer to their work place. Other wishes/preferences such as access to transit, demographic factors, affordability, etc. are more important (Wolday et al. 2018).

In this thesis, the standard measures of diversity such as entropy are not included in the analysis. Instead, the thesis attempts to reflect on operationalization of land-use diversity by analyzing the effect of accessibility from residence to different land-use types at different spatial scales (neighborhood vs city scale).

2.2.4. Design and distance to transit

Using built environment as an effective intervention to redirect mobility towards sustainable alternatives often requires a host of built environment attributes at different scales working in tandem. Design factors are microscale built environment interventions that are implemented at the neighborhood scale. Design factors encompass physical design aspects such as block size, street network design, availability of sidewalk, and bike- and footpaths that primarily influence the feasibility of non-motorized transport. Design factors may also include aesthetic aspects, which Ewing and Handy (2009) called urban design qualities, that make a journey pleasurable or attractive such as scenery along the way, imageability, legibility, transparency etc. Similar design aspects are also prescribed as a way to cultivate a sense of community in contemporary neighborhoods. Since the focus of this thesis is on the mobility effects of built environment, this last segment will not be discussed.

Distance to transit is another micro-scale built environment attribute with important implication for transit use. Similar to other travel modes, travel time accounts for a large share of the generalized travel cost associated with transit transport. The time component of travel cost by transit comprises of access/egress time, waiting time, in vehicle time, and transfer time. Reducing the access/egress time has a significant implication to transit ridership. A distance of about 1 km (a half-mile is also used often) is often referred to as the acceptable distance for transit accessibility at both ends of a journey. However, the empirical support for why precisely a 1 km or a half-mile (which is about 800 meters) of transit catchment area is debatable, because people are generally willing to travel further to trains than to buses. Moreover, demographics have strong influence on what one considers acceptable distance (Daniels & Mulley 2013). Nonetheless, several studies deem a distance of 1 km to be a good approximation of the effective geographic scale for walking as an access/egress mode (Guerra & Cervero 2013; Millward et al. 2013; Scheiner 2010; Zhang & Xie 2015). In general, accessibility to transit is reported to increases transit use (Ewing & Cervero 2010). When accessible transit facility is combined with design factors that enhance the feasibility and attractiveness of walking/cycling along the routes, access to transit is likely to stimulate both transit ridership and the use of non-motorized modes as access modes (Ewing & Cervero 2001; Handy 2015; Hess 2009).

2.2.5. Demand management

Many built environment interventions need the support of travel demand management measures to facilitate sustainability oriented travel behavioral changes. Demand management measures include fiscal (road pricing, congestion pricing, parking pricing) and non-fiscal or land-use related measures (traffic calming, parking regulation). The majority of demand management measures are designed to discourage car use and raise the competitiveness of public transit. Road/congestion/parking pricing raises the cost of car travel while traffic calming measures and parking regulation increase the travel time raising the viability of public transit (and to some extent walking and biking) as an alternative travel mode to a car. For demand management measures to be effective however, they need to be preceded by an accessible, affordable and efficient public transit service. Otherwise, demand management regimes would be perceived as merely fiscal and unfair.

2.3. Geographic context

The effectiveness of land-use factors in both containing transportation demand and ameliorating its adverse environmental effects is contextual. Therefore, the issue of geographic context has a strong bearing on the overall travel volumes and modal split of an individual. Land-use attributes proven to work in some places may only have a slight influence on travel behavior in other places due to differences in scale, policy, or/and synergy between different built environment factors (Milakis et al. 2015; Niemeier et al. 2011; van Wee & Handy 2016; Zhang et al. 2012). Geographic context (urban size, regional context and scale) as well as the interconnectedness among built environment attributes are the frequently cited reasons for the lack of universality or external validity of findings (Bhat & Guo 2007; van Wee et al. 2013).

The travel behavior of a person residing in a small city, which is located adjacent to a larger city, is likely to be a cumulative outcome of the wider regional context. Urban features at the neighborhood scale affect travel outcomes at the local level (Milakis et al., 2015; van Wee et al. 2013, PP. 88-89). They also interact with the small city's local urban structures (residential distance from the city center) to influence regional travel patterns, for example, commuting mode choice.

In a small city context, three geographic scales can be identified with presumably significant effect on travel behavioral outcomes. The neighborhood scale, the local scale or city-scale and the regional scale. Built environment at the neighborhood scale include factors such as density, accessibility, street connectivity, etc. within close vicinity (often within a kilometer) of the residence.

2.3.1. Urban size

The extent of influence that the built environment exerts on travel behavior varies by city size (Hu et al. 2018; Sun et al. 2016; Zhang et al. 2012). Density, diversity and distance to transit are among the prominent factors with strong potential influence on travel behavior (Cervero & Kockelman 1997; Ewing & Cervero 2001; Ewing & Cervero 2010), but their influence is contingent on the city size in which they occur. The effectiveness of density in stimulating diversity in land-uses and fostering efficient public transport is conditional on the size of a given city. Both commercial establishments and public transport provision require a certain critical mass of potential customers located within feasibly accessible range (Christaller 1966).

In Norway, densification in city centers is a land-use policy of choice to reduce carbon footprint from transportation, reduce urban pollution and counter urban sprawling (Norway's Governmet 2014).

Although smaller cities are characterized by monocentric city structures, the low population size in these cities may limit the diversity of facilities and therefore their attractiveness as potential destinations. Hence, for small-city dwellers, the significance of the city center as a major trip generator will, in part, likely depend on city size. As a result, small-city dwellers may, for a variety of facilities, depend on locations other than those in the city where they reside. Whether neighboring, higher-order destinations can be viable alternative destination, however, is an empirical question, which depends on the position of the small city in a regional center-hierarchy of cities and its proximity to the nearest higher-order city.

2.3.2. Regional context

At a regional scale, cities of different size and hierarchy dot the landscape at various distances from one another. These cities are not just random in their distribution but display some hierarchical pattern as proposed by central place theory (Christaller 1966; Lösch 1954). Dictated by the critical mass of potential customers required to support a given firm, the number and diversity of facilities is limited by the size of a given city. Higher order cities are characterized by greater specialization, higher economies of scale and provide higher diversity of goods and services compared to their lower order counterparts. Consequently, we find many medium to small sized lower-order cities scattered in space around a higher-order city.

The geographic proximity and connectedness between the urban entities dictates that the lower-order cities are economically and culturally integrated, to varying degrees, into the fabric of the major regional city. For many of the lower-order cities, the regional pull factors are likely to vary depending on the size of the local economy, size of the higher-order city, distance and connectedness to the higher-order city. Depending on the extent of regional influence, some of the lower-order cities can be perceived as satellite cities. When small cities are in close proximity to their higher-order counterparts, the travel patterns of residents in the satellite cities will be reflective of the regional context. While others, often due to distance decay, will be spatially less dependent on the higher-order center and therefore experience weaker pull factors from the nearest higher-order center.

One important manifestation of regional influence is commuting pattern. Individuals tend to tolerate longer trips and greater travel time for subsistence (earning a living) or obligatory activities (Hägerstraand 1970; Jones et al. 1983). The concept of travel time ratio[8] refers to the relationship

[8] As used here, travel time ratio is defined, following Dijst (2000), as the ratio between travel time to an activity and the stay time performing the activity.

between travel time and stay time at the destination. Several studies (Dijst & Vidakovic 2000; Schwanen & Dijst 2002) found that travel time exhibits proportionality to the duration of activity and that the travel time ratio is higher for mandatory trips such as job commutes than for discretionary trips (Dijst & Vidakovic 2000). The subsistence nature of job commuting accords commuting travel a wide tolerable range of travel time (Dijst & Vidakovic 2000; Kitamura et al. 1997; Ma & Goulias 1998). In today's work arrangements, duration at workplaces is by far greater than any other out-of-home activity duration per day.

Since individuals tend to choose the best facilities within a category given that facility is accessible within an acceptable time/distance range (Næss, 2006, pp. 72-94), the higher tolerance range for commuting trips lays out for a wider action space and longer job commutes. As a result, residents in small cities that are in adjacent locations to higher order cities have a disproportionate share of their workforce commuting to the higher order centers for better jobs and end up commuting longer average distances (Næss, 2006). The greater average travel time by suburban commuters takes a large share of the ideal daily travel time budget (Mokhtarian & Salomon 2001; Mokhtarian & Chen 2004) individuals would want to spend on trip making, ultimately shrinking the feasible action space (time-space) available for other non-work activities[9]. Therefore, other non-work daily activities have to be organized in close quarters to the base facility (home) and also supplemented by trip chaining. Consequently, understanding the dynamics of local travel in small cities as well as investigating for environmentally sound means of commuting is an important quest for sustainability.

Moreover, for small and medium-sized urban areas, understanding travel behavior within a regional context is relevant for planning for a multiple of reasons. One of the reasons relates to the regional population share that live in small cities. In a given region, for every major city there are many lower-order cities scattered around it that account for a sizable cumulative share of the regional population. Another reason relates to the fact that small-to-medium sized cities are to a large extent car dependent; therefore, planning efforts that intend to reduce transportation-related adverse environmental effects cannot deliver without proper understanding of the dynamics of travel behavior in these cities.

[9] The shrinkage of time available for non-work activities due to longer job commutes may have important implications on quality of life aspects, which can be a subject for future research.

3. The issue of causality in the relationship between Land use and travel behavior

Deducing causality in a stimulus-response type of relationship between events, circumstances or objects is an established way of generating and consolidating knowledge. Causality occurs when patterns, structures and characteristics underlying a certain social or natural phenomenon could be explained by the occurrence of another independent phenomenon. Research in regional science, similar to other fields of science, strives to establishing causation, for example, between urban structure and travel patterns as this can potentially enable planners to intervene and alter future course of events to socially desirable outcomes.

The relationship between urban structure and travel behavior is a complex one as it involves a myriad of interrelationships between multiple factors with multidirectional causal loops interacting in open systems[10] (Danermark et al. 2002; Fleetwood 2017). The travel behavioral outcome is a result of cultural, economic, demographic and physical structural factors all interacting with one another. What we can observe and hence measure from empirical data is unlikely to display the causal intricacies that brought about the result. In such a complex situation, the type of knowledge we can produce and the appropriate methodology we adopt to reach it is tantamount to having clarity at the ontological level.

Urban research is fraught with context specific and at times contradicting results. Both lack of external validity and inconsistent results can mean that the causal flows are either not properly understood or/and a different recipe of causes and causal flows is active under different circumstances. The debate about whether and to what extent built environment affects travel behavior is still alive partly because of the vague understanding about the nature of causation and the ontological basis underlying that (Næss 2009; Næss 2014; Næss 2015).

My philosophical point of departure in understanding knowledge generation is inspired by and anchored on the critical realist thought in philosophy of science. Unlike in the positivist epistemology (e.g. David Hume's account of causation (Lacewing 2017)), human senses or the experiences of our surrounding such as observing regularities between events are not adequate to display the multitude and intricate causal networks between actual or potential events. For critical realism, reality exists independent of our knowledge of it. This reality, the mechanisms that cause events to occur, exist beneath the level of

[10] Parts of the social world is characterized by (stochastic and/or probabilistically specified) regularities between events or states of affairs of the form 'whenever event or state of affairs x then event or state of affairs y', are closed systems, and parts of this world not characterized by such regularities are open systems (Fleetwood, 2017)

observable phenomena or events. Knowledge generation, in the critical realist epistemology is hence about uncovering the inner working at play in bringing about a certain event or outcome. It is about the study at the level of mechanisms and not the regularities of readily observable phenomena at the level of events (Danermark et al. 2002).

Critical realism provides a useful background to understanding why empirical findings in regional science (those mainly grounded in Humean empiricism) lead to inconsistent and at times contradicting results. From a critical realist perspective, a causal statement is not about regularities between objects and events but about the inherent causal powers and tendencies that objects or structures possess. Four concepts make up the tenets of the causality perspective in critical realism: structures, powers, generative mechanisms and tendencies. Structures such as built environment have causal powers by their nature. These causal powers are understood as tendencies, as the potential (exercised or not) to be a cause and lead to an effect when triggered.

The very notion of causal tendency implies that these powers are not always reactive and therefore a generative mechanism needs to be triggered for the causal powers to be exercised. Even when triggered, the outcome is unlikely to be the same every time a mechanism is triggered as other incidental and contextual mechanisms are likely to be simultaneously acting out. Danermark et al. (2002, p.56) sums this relationship as follows: “objects have powers whether exercised or not, mechanisms exist whether triggered or not and the effects of mechanisms are contingent”. The social world is a complex one. An event is an outcome of several concurrent mechanisms, some counteracting yet others supporting or amplifying others. Consequently, causal connection or causal laws (well substantiated empirical regularities of the type ’if A then B’) have to be analyzed as tendencies (Bhaskar, 1978, P. 50).

In relation to the subject matter of this thesis, a structure such as built environment has, by virtue of its very nature, the tendency to cause people to travel in certain ways. High density, that creates the conditions for bringing origins and destinations closer together, may cause people to travel shorter, reduce car driving, induce more active travel etc. Higher accessibility to public transport may increase ridership and reduce car driving. All these outcomes are plausible and potential results of the causal powers that urban structures possess. In a small city though, the generative mechanism of high density leading to more sustainable mobility may not come about or may be highly discounted because the scale of the city may limit the possibility of public transport and other important facilities from taking foothold. Although these built environment factors have causal tendencies, the effects they produce are contingent on what other mechanisms they combine with. The same built environment attributes that were found to generate certain type of effect may lead to different outcome (no effect, greater/less effect) depending on the geographic scale, institutional setting, city-center structure, customs and personal attitudes, etc.

One cannot objectively conclude about the existence or lack thereof of relationships between built environment and travel solely based on econometric results without looking deeper in to the mechanisms that are triggered, remain dormant and/or are counteracted in the different circumstances under which research is carried out. In an urban environment where pubic transport lacks the desired spatial reach and efficiency, many of the land-use interventions that are believed to move people from cars to public transport are likely to be ineffective. However, empirical estimates that render the land-use variables insignificant only conclude so given the pertinent conditions surrounding the research environment, hence does not mean it nullifies the causal tendencies urban structure has. Unless there is a universal structurally constraining mechanism, there is nothing that prohibits the same variables from being significantly associated under a different circumstance.

Critical realism identifies two sides of knowledge. One constitutes the intransitive objects of knowledge also called the causal laws, which is conceptualized as structures and mechanisms that exist and operate independent of our knowledge and experience of them. The second side of knowledge however is composed of the transitive objects of knowledge. Transitive objects of knowledge constitute artificial (as opposed to natural phenomena) human constructs such as models, theories, techniques of inquiry, etc. produced by the prevailing scientific knowledge. Transitive object of knowledge is ontologically distinct from the intransitive objects of knowledge.

Intransitive objects of knowledge generate sequences of events that we may or may not be oblivious to. The function of transitive objects of knowledge is therefore to provide us with techniques of enquiry by which to make sense of these events and the processes that generated them. However, for events to be subjects of investigation we have to first make account of them, have experience of (perceive) them. Nevertheless, the occurrence of events and our perception of them is not consequential either. In Baskars' words, "Events then are categorically independent of experience. ………. Certainly if at some particular time I have no knowledge of unperceived or unperceivable event, I cannot say that such an event occurred".[11]

[11] (Bhaskar 2008), page 32.

These last phrases bring us the identification problem imbedded in causality analysis. The fact that events are not necessarily perceivable obscures the message a causal law (an intransitive object of knowledge) relays to us and complicates the identification of the cause and the caused on the one hand and the direction of causality on the other.

3.1. Statistical (econometric) methods for causal inference

Research in regional science has rigorously utilized statistical methods in studying the dependence of an endogenous variable on one or a set of exogenous variables. Any statistical analysis starts by specifying a model, and the basis for these models is some prior knowledge or theory (outside the realm of statistics). Consequently, the estimates are as good as the models we specify, as regression cannot guarantee causality in its own right, no matter how strong the association between variables might appear to be, unless the underlying theory has a solid factual basis. Kendal and Stuart (1961) explain “a statistical relationship, however strong and however suggestive, can never establish causal connection: our ideas of connection must come from some theory or other”[12].

To quote Bhaskar (2008) “Critical realism maintains that scientific method necessarily involves observation of events but due to the deep dimension of reality it cannot be reduced to observation of phenomena at the empirical level. To acquire knowledge, it is essential that we know the mechanisms that caused them”. Provided they are done right, i.e. causation is understood as tendencies and a plausible theoretical underpinning of the mechanisms at play precedes model specification, statistical methods is one important tool of scientific inquiry.

The ability to identify the mechanisms, by which the events we experience come about, enables us to isolate the noise from the causal objects. And in the cases where a multitude of objects simultaneously or sequentially act (which is a norm rather than an exception in social science) to generate a certain set of events, identifying the causal mechanism could be a tool in identifying the hierarchy of relevance between the causal agents.

Statistical analysis has been the modus operandi in land-use and transportation research and has made great strides in rigor and sophistication. However, no matching advances were made on the epistemological fronts to guide model specification (Næss 2015) and harmonize contextual peculiarities. The literature on the relationships between land-use and travel behavior is vast but messy with rarely

[12] Schlotter, M., et al. (January 2010). "Econometric Methods for Causal Evaluation of Education Policies and Practices: A Non-Technical Guide." IZA Discussion paper series **IZA DP No. 4725**: 39

the same land-use measures and often with diverse methods in data collection and variable definitions as well as murky terminologies (Ewing et al. 2014; Handy 2017; Næss 2009; Næss 2013). When adopting models from previous studies, scale differences between cities and the potential differences in urban settings are also rarely reflected upon (Wolday 2018a).

Largely, the focus of empirical research in the field has been on refining the precision of statistical methods rather than the theoretical foundations on which the models are supposed to be based. As Næss (2015) explains, "mainstream research on influences of the built environment on travel is much more preoccupied with *doing the things right* (making methodically correct statistical analyses) than with *doing the right things* (to include the relevant independent built environment variables and control variables while avoiding to include irrelevant control variables)." Empirical analysis that is not based on coherent theoretical foundation is prone to produce miss-specified models, which is a very serious source of bias in empirical estimates (Lewis-Beck 1980; Wooldridge 2014). One such phenomenon in the literature on the relationship between built environment and travel behavior is the issue of travel induced residential self-selection.

Travel induced residential self-selection will be elaborated further under the next sub-section to illustrate the need for prior knowledge about causal mechanisms before setting up the statistical model.

3.2. Travel induced residential self-selection

The debate on the influence of built environment on travel behavior and hence the viability of land-use policies in mitigating transport related negative effects is often questioned based on two lingering arguments. One relates to the debate as to whether there is a credible influence of land use on travel behavior while the other relates to the magnitude of influence built environment has on travel behavior. Although the debate around causality between built environment and travel behavior is largely settled, consensus is still illusive in the scientific community as to when self-selection may in fact be a problem (Cao et al. 2009a; Cao & Chatman 2016; Schwanen & Mokhtarian 2005; Van Wee 2009), the extent of discounting effect self-selection might impart (Ettema & Nieuwenhuis 2017; Wolday et al. 2018), and whether at all self-selection should be an issue for concern (Chatman 2014; Næss 2009; Næss 2014).

Travel induced residential self-selection refers to the assumption that people tend to choose their place of residence based on how they want to travel. In a thought experiment, this makes a good sense. If we assume that mode choice is determined exogenous to built environment and that people first decide how to travel and then choose a location that enables usage of the preferred mode, then built environment would be merely mediating the effect of whichever factors influence mode choice.

By way of example, let's assume that those who prefer to travel by car choose locations that are conducive for driving (e.g. low-density neighborhoods) and those who prefer to travel by transit choose transit neighborhoods (high-density neighborhoods with high transit access). Now, if an empirical study were to be conducted on the effect of built environment on travel behavior in neighborhoods such as the two in our example above, our estimates would show that density has strong negative association with driving and an apparent strong positive association with transit use. Because residents are predisposed to choose their residence in a certain way due to their travel preference, the effect of built environment would be amplified further and would be biased upwards. If residential self-selection is as simple and straight forward as in our example, then travel preference has to be controlled for in order to get to the truer effect of built environment.

In the real world, residential selection process is a complex multi-criteria constrained optimization of which travel preference is but one. Several conditions ought to be met for travel-induced residential self-selection to be an issue for concern. First, travel preference has to be strong as a criterion in the selection of residential location. Previous findings indicate that travel preference marginally trickle down to residential selection (Ettema & Nieuwenhuis 2017) but only as a second tier (Cao 2008; Filion et al. 1999; Wolday et al. 2018) after other, more important criteria such as affordability and safety are satisfied.

The second condition relates to a subtle underlying assumption that transit neighborhoods and driving-oriented neighborhoods are substitutes and that individual's preference between them is mutually exclusive. The assumption implies that, given the option, those who prefer transit would move to transit neighborhoods while those who prefer driving will gravitate towards neighborhoods that are more conducive for driving. A qualitative study recently conducted in Oslo, Norway found that individuals with high transit preference tend to self-select towards transit neighborhoods, but residential selection due to high preference for driving is seldom observed (Wolday et al. 2018). The same research also found that demographic factors are the main reasons why people move away from transit neighborhoods.

Third, for the travel induced residential selection proposition to be valid, geographical differences in the conditions for car driving and/or the conditions for transit travel should enable individuals to self-select. In an environment where driving is the norm and where access to transit service is generally negligent, claiming travel induced residential self-selection is void of meaning. Preference is an integral part of the demand for a good or service. For the most part, people travel by a certain mode because of their preference to do so, which, in part, is a result of the availability of other travel options. However, when there is no other service to weigh it against, it becomes empirically difficult to disband travel preference from the preference to travel by car.

The issue of travel induced residential self-selection is now so standardized in the scientific community that its validity is taken for granted. Many researchers are compelled to control for travel related attitudes in order to disband bias from built environment factors. Rarely do researchers reflect upon whether the bias they intend to purge cause an upward or downward bias on the effect of built environment on travel. Neither do many scholars reflect on the plausibility of the assumptions underlying travel induced residential self-selection.

To meaningfully assert the existence of causal link, at least five criteria ought to be met (Schutt 2015; Singleton & Straits 2010). First, empirical association – a significant statistical relationship[13]. Second, appropriate time precedence - cause precedes effect. Third, non-spuriousness – a relationship that cannot be attributed to another variable. Forth, causal mechanism – identifying logical explanation on how and why the alleged relationship should produce the observed effect. Fifth, context - specifying the context in which the effect occurs.

The first three of the above criteria, often referred to as a group as nomothetic causal explanation, can be handled by statistical methods fairly well. Although nomothetic causal explanations are ideally suited in experimental research, a cautious and skillful use of statistical methods can still be used in real world observations to reveal randomized statistical properties that resemble experimental research. Still, the first three criteria can tell us little about causal flows. Investigating the causal mechanisms through which the cause brings about the effect as well as awareness of how the research context conditions the causal mechanisms is crucial to robustly infer causality. In fact, non-spuriousness is in itself a specification problem, which is difficult to detect using statistical methods alone unless there is a priori knowledge of the mechanisms at play.

[13] A causal effect could be masked by counteracting influences rendering the bivariate association non-significant. Hence, the empirical association requirement should always be thought of in a multivariate setting where all relevant influences are specified, .i.e. simultaneously satisfying the non-spuriousness requirement.

4. Research design, data and method

4.1. Research design

The research is designed around the core research questions on the relationship between built environment and travel behavior in a small city context. The premise for this thesis is that the relationship between built environment and travel behavior is geographically contextualized. The effect of built environment on travel can be either fully active, active but discounted, or suppressed/dormant depending on the geographic scale or urban size one considers. Although the outcome of the relationship between built environment and travel is likely to be conditional on urban size, especially for smaller cities, small cities are rarely covered in urban research. Moreover, comparisons across studies in review articles and meta-analyses (Ewing & Cervero 2010; Stevens 2017) rarely take into account the contextual nature of built environment attributes and especially the size differences between cities they are obtained from. To contribute in amending the literature gap, this thesis is primarily focused on small cities.

Table 1 presents an outline of the research questions and the information required to answer them. The primary source of data is a survey conducted in three small cities from the south-eastern part of Norway. Previous survey questionnaires[14] from travel surveys and published articles (Handy et al. 2005; Hjorthol et al. 2014; Næss 2005; Næss 2007b) were consulted in identifying relevant variables.

Research in urban planning routinely controls for socio-economic and demographic heterogeneities between individuals when investigating the causal association between built environment and travel behavior. Controlling for travel-induced residential self-selection is also another trait regularly accompanying such research with an intention to get to the true effect of urban structure on travel behavior. Since how researchers understand and operationalize travel-induced residential self-selection has an important bearing on empirical outcome, the thesis addresses the issue of travel-induced residential self-selection using a complementary data source from Oslo metropolitan region, the largest metropolitan region in Norway.

[14] Questionnaires from previous surveys in Copenhagen, Denmark (Næss, 2005); Hangzhou, China (Næss, 2007); Norwegian national travel survey for 2013/14 (Hjorthol et al. 2014); and the RESACTRA project in Oslo and Stavanger, Norway (Næss et al. 2018) were consulted for a broader perspective on questionnaire design. In addition, the study drew insights from Handy et al. (2005) on specification of variables pertaining to residential preferences and travel attitude.

Table 1. An outline of research themes, research questions, information required, and data sources.

Research themes and underlying questions	Data/information requirement	Data source
I. Travel attitudes, residential self-selection and travel behavior: *Investigate the role of travel attitudes on the causal relationship between built environment and travel behavior.*		
• How important is transit preference in the choice of transit zones? • How does transit use differ between consonant and dissonant residents? Consonant residents are residents whose transit preference matches their neighborhood characteristics whereas dissonant residents are those whose transit preference mismatches their neighborhood characteristics • Why do transit-favoring residents live in transit-poor zones?	• Whether the resident lives within a zone of high transit accessibility • Residents' travel activity by motorized modes (private car and transit) • Demographic & socio-economic attributes • Residential preference indicators • Availability of mobility resources (driver's license)	• Survey data from Oslo metropolitan region • Addresses of residential homes from public property register (www.Infoland.no) • GIS-generated spatial data such as distance to transit and stratification of the urban region • Location of transit stations from digital maps
• Which underlying mechanisms are at play when individuals choose their place of residence and how do different selection criteria (including travel attitude) factor in the selection process?	• Information about residents' rationales and perceptions regarding their residential location choice, activity participation, travel decisions and insights based on retrospective and hypothetical questions about travel behavior in a different residential situation.	• Semi-structured face-to-face interviews in Oslo metropolitan region about motives for choices of place of residence, trip destinations and modal choices
II. Urban structure, regional context and car driving distance: *Investigate whether car driving distance vary significantly with variations in residential distance from the city center in a small-city context*		
• How does the relationship between car driving distance and residential distance from the city center manifest itself after controlling for differences in demographics, socio-economic attributes and residential preferences? Questions pertaining to the effect of socio-economic and demographic attributes on travel behavior	• Residential distance from the city center • Other built environment characteristics at neighborhood-, local/city-, and regional-scale	• Survey data from three small cities with diverse city-center structure, regional context and population size ranging between 10 000 and 20 000 inhabitants • Addresses of residential homes from property register (www.Infoland.no)

while controlling for residential distance from the city center are also addressed here • How does the relationship between car driving distance and neighborhood-scale built environment factors behave after accounting for residential distance from the city center, and differences in socio-economic and demographic attributes? • How important are neighborhood and city-scale built environment factors in influencing total driving distance in the context of regional influence?	• Resident's car driving distance during a period • Residents travel activity by transit • Demographic attributes & socio-economic attributes • Residential preference indicators: opinions about preferred residential and neighborhood characteristics if the resident were to move to a new location	• Statistics Norway, register based employment data showing commuter flow patterns (www.ssb.no) • GIS-generated spatial data such as residential distance from the city center, and residential distance to various facilities (job location, transit station)
III. Built environment, city-center structure and non-work active travel: *Identify important built environment attributes influencing non-work trip frequency to different destinations in a small city context* • Explore travel attitude's direct and indirect effect (indirect effect via interaction with built environment-factors) on the extent of active travel • Investigate the effect of differences in city-center structure and the associated distribution of various facilities (destinations) on active travel. City-center structure, as used in this paper, refers to the categorization of a small city as either single-centered or multiple-centered (polycentric)	• Residents' travel activity to non-work destinations by non-motorized modes during a period • Built environment characteristics at neighborhood scale (disaggregate neighborhood accessibility index, intersection density, population density) • Built environment characteristics at the local/city scale (residential distance from the city center, city-center structure) • Demographic & socio-economic attributes • Residential preference indicators • Distribution of facilities in the urban space • Attitude towards active travel	• Survey data from three small cities with diverse city-center structure, regional context and population size ranging between 10 000 and 20 000 inhabitants • Addresses of residential homes from property register (www.Infoland.no) • Register-based data on commercial and non-commercial service establishments from Statistics Norway (www.ssb.no) • GIS-generated spatial data such as residential distance from the city center and various service facilities • Geo-coded spatial data on employment density and job density from Statistics Norway (https://www.ssb.no/natur-og-miljo/geodata)

IV. Neighborhood design factors with a tendency to stimulate higher rates of active travel: *Which factors influence people with high attitude towards active transport to underperform in their walk/bike trip frequency and how can they be stimulated to walk/bike more?*

• Among those with high positive attitude towards non-motorized travel, what distinguishes those with low levels of active transport (low-active-transport dissonants) from the ones with high levels of active travel (high-active-transport consonants)? • For those who are motivated (individuals with high positive attitude) but currently performing low levels of active transport, which neighborhood characteristics can contribute to increase their active transport magnitude?	• Residents' travel activity to non-work destinations by non-motorized modes during a period • Built environment characteristics at neighborhood scale (disaggregate neighborhood accessibility index, intersection density, population density) • Built environment characteristics at the local/city scale (residential distance from the city center) • Demographic attributes & socio-economic attributes • Residential preference indicators • Distribution of facilities in the urban space • Attitude towards active travel	• Survey data from three small cities with diverse city-center structure, regional context and population size ranging between 10 000 and 20 000 inhabitants • Addresses of residential homes from property register (www.Infoland.no) • Register-based data on commercial and non-commercial service establishments from Statistics Norway (www.ssb.no) • GIS-generated spatial data such as residential distance from the city center and various service facilities • Geo-coded spatial data on employment density and job density from Statistics Norway

The data from Oslo metropolitan region was collected as part of a larger project (the RESACTRA[15] project) and includes both quantitative and qualitative data. The combination of qualitative and quantitative data as well as the transport options available in the case area (Oslo metropolitan region) makes the data particularly suited to address the issue of travel-induced residential self-selection and how it relates to travel behavior.

The following sub-sections briefly describe the case areas, the surveys, relevant variables and the methods employed.

4.2. The survey

4.2.1. The small-cities survey

The survey was conducted in three small cities of Kongsvinger, Jessheim and Drøbak in the municipalities of Kongsvinger, Ullensaker and Frogn respectively in 2015 (reference maps are presented by figures 3 to 5 further below). The population in the continuous built-up area of the three cities ranges between 10 000 and 20 000 inhabitants (table 2). Size of the city (population), population density in the continuously developed area, city-center structure, regional context and available transportation networks were relevant attributes considered in selecting the case cities.

The three cities are comparable in terms of population size. Nonetheless, Kongsvinger stands out somewhat with a lower population density[16].

Table 2. Aggregate description of survey areas

Settlement areas (small cities)	Number of residents	Area (km^2)	Population density (per km^2)	Share of municipal population
Drøbak	13405	5.52	2428.4	86 %
Jessheim	16595	6.84	2426.2	51 %
Kongsvinger	11969	7.87	1520.8	67 %

Source: (Statistics Norway 2015)

To mitigate the continuously declining[17] response rates in Norway and elsewhere (Amundsen & Lie 2013), the gross sample included more than 90 percent of the residential units in the continuous built up areas in each of the three cities. The survey sampling frame encompassed all residential units in the continuous built-up area of the three cities. Potential respondents between the age of 18 and 75 were

[15] A project about residential location, activity participation and travel behavior with surveys and qualitative interviews in metropolitan regions of Oslo and Stavanger. The project was financed by the Norwegian Research Council, had a 3.5 years span and ended in June of 2017.

[16] The spatial context for the population size and land area is the continuous built up area.

[17] Response rates for travel surveys often range between 10 and 20 percent (Hjorthol et al. 2014; Næss 2016).

randomly selected from the adults in each residential unit resulting in a sample of 4591, 5609, and 5074 potential respondents from Kongsvinger, Jessheim and Drøbak respectively.

The survey was conducted using a self-administered web-questionnaire. An invitation letter was sent to each potential respondent in December 2015 with information on the purpose of the survey, how to access and complete the survey and contact information. The survey did not use follow-ups in the form of reminders. Instead, respondents who completed the survey were eligible for a gift card lottery worth 6 000 NOK (approx. USD 750) to incentivise participation. The response rates were 11.1 %, 11.0 %, and 16.6 % for Kongsvinger, Jessheim and Drøbak respectively. Although the response rate was low, it is within the mainstream for surveys administered to the general population.

To insure diversity on important urban structural attributes among the case cities, three criteria were considered in selecting the survey cities: regional context, city-center structure and transportation network. Hence, the case cities represent three different urban structural conditions both locally (city center structures) as well as in their role in the urban hierarchy in the wider regional context. Jessheim and Kongsvinger have monocentric city-center structures with most of the commercial and other service facilities concentrated in the city center, although the density of facilities is higher in Jessheim than in Kongsvinger. The city centers in both cities also offer a train station and a bus station.

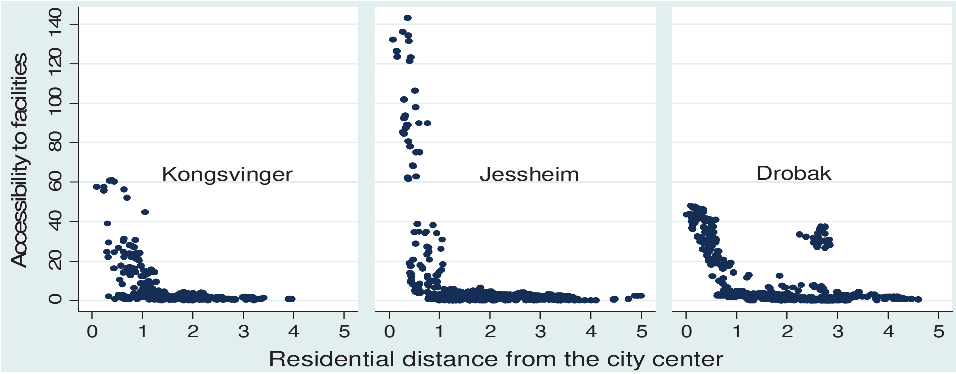
In contrast, the city of Drøbak has two competing centers. The city market (Torget) close to the harbor is traditionaly considered as the main city center. The second center, AMFI-Drøbak, is a recent development with shopping centers and other service-rendering facilities at the outskirt of the city. Both centers in Drøbak have a significant number of facilities but the largest shopping facilities are located at AMFI-Drøbak. The two centers are about 3 kilometers apart.

The contrast in city-center structure among the three cities is reflected by the distribution of facilities with respect to the city centers as shown by figure 1. The vertical axis shows the cumulative accessibility[18] to facilities while the horizontal axis represents residential distance (in kilometers) from the city center. Cumulative accessibility to five facility groups is measured using weighted gravity model. The facility groups comprise of grocery stores, restaurants and cafés, facilities for errands other than

[18] A potential accessibility indicator is measured using gravity model. The accessibility values show the number of potential facilities accessible to each residence at a distance of half-mile (805 meters). The facilities comprise of grocery stores, medical facilities (medical clinics, dental clinics and pharmacies), restaurants and cafés, facilities for errands other than grocery stores, and fitness centers.

grocery stores, fitness centers, and medical facilities such as medical clinics, dental clinics and pharmacies.

Figure 1. Distribution of accessibility to facilities in the cityscapes



Regionally, Drøbak and Jessheim are located at a comparable distance along the road network from Oslo, at respectively 39 and 45 kilometers away from the city center of Oslo at opposite ends of the Oslo metropolitan region. Both cities are connected to Oslo with well-functioning road networks. The two cities do differ, however, in terms of railway infrastructure linking them to Oslo. Jessheim is integrated into the rail network with scheduled train departures to Oslo every half hour while Drøbak is not integrated into the rail network. Unlike Drøbak and Jessheim, Kongsvinger is located furthest away from Oslo, at a distance of 96 kilometers along the road network. Kongsvinger is integrated into the rail network and has an hourly scheduled train departure to Oslo.

The size of the city combined with the connectivity and proximity to a higher order center determines the center hierarchy of the city, which in turn will likely influence travel outcomes. Using Commuter flow patterns (Aguilera & Mignot 2004) between the case cities and the adjacent urban areas, the cities are defined as either regional centers or satellites. Table 3 summarizes commuter flow pattern for the municipalities where the case cities are located.

Kongsvinger, with its secluded location away from regional influences of other major cities, is more self-contained and has a smaller proportion of its labor force out-commuting. In 2015, 71 percent of the resident labor force in Kongsvinger municipality were locally employed whereas the corresponding figures for the municipalities containing Drøbak and Jessheim were about 37 and 49 percent respectively[19]. On the basis of commuter flow data and proximity to a higher order urban area, Kongsvinger is defined as regional center while Drøbak and Jessheim are defined as satellites.

Table 3. Number of individuals employed and commuting flow by county of residence

County of residence	No. of residents employed	Working in home county (%)	Share of out-commuters (%)	Out-commuters to Oslo (%)
Frogn	**7889**	37 %	63 %	31 %
Ullensaker	**17329**	49 %	51 %	24 %
Kongsvinger	**7678**	71 %	29 %	8 %

Source: *Statistics Norway, register based employment data. 4th of quarter 2015*

4.2.2. Survey in Oslo metropolitan region

The survey on small cities is supplemented by additional data from the Oslo metropolitan region. The data from Oslo metropolitan region is specifically used to address a lingering debate about the role of travel-induced residential self-selection on travel behavior. The city of Oslo is by no means a small city and does not fit in to the geographic scale the thesis is interested in investigating. However, the city of Oslo, as a case, is best suited for the task at hand (investigating travel-induced residential self-selection). Diversity in transport systems among neighborhoods, which can enable individuals to self-select (e.g. choose car-oriented or transit-oriented neighborhoods), is vital for the concern of travel-induced residential self-selection to be justified. Oslo has an extensive public transportation network in the central area of the city while the suburbs are car dominated. The methodological lessons learned from the self-selection study in Oslo helps inform model specification in the rest of the thesis.

The data utilized in this study came from a self-administered nine-page web-survey carried out in the Oslo metropolitan region in 2015. The study is part of a larger project comprising of two metropolitan regions of which Oslo is one. The survey was tailored to examine built environment impacts on travel behavior of the general population as well as recent movers. The data collection scheme comprises of a survey for collecting quantitative data and a qualitative part based on discursive interviews. In Oslo metropolitan region, a total sample of 15,000 individuals were drawn using a combination of purposive and stratified random sampling.

After identifying individual addresses with the help of real estate developers, realtors' websites, the online mapping and address service (www.finn.no), and the population register, 2500 individuals were

[19] Statistics Norway, register based employment data, 4th quarter, 2015. (https://www.ssb.no/en/arbeid-og-lonn/statistikker/regsys. Visited March 28, 2018)

randomly selected from newly relocated individuals while the remaining 12,500 units were randomly drawn from a geographically stratified sampling frame.

Similar to the small-city survey, we sent an invitation letter to each individual in the sample with information about the survey and a guide on how to respond. In total, we received 1904 acceptably completed questionnaires, yielding a response rate of 13.3%.

Participants for the qualitative interviews were recruited among questionnaire respondents who had stated their willingness to be interviewed. The interviewees were selected from different residential locations (central city, close to second-order centers and non-central location) and varying population groups in terms of household composition, employment and education. Altogether, 17 interviews were carried out, six from the central city, three from locations close to second-order centers, and eight from non-central location of the metropolitan region. The interviews, each lasting for 1–1.5 hours, were audio-recorded and transcribed. Topics addressed in the interviews include, among others, interviewees' reasons for living in their residential neighborhood, assessment of the residential neighborhood's opportunities and constraints in terms of travel as well as their reflection on activity patterns and travel behavior if they were to be living in a different kind of residential location.

The interviews were first audio taped and then transcribed word-for-word. The transcribed interviews were interpreted with the help of an interpretation scheme containing 45 thematic categories. Interpretation of one or a set of interrelated sub questions in the scheme were carried out by two researchers independently who later harmonized their interpretations. A detailed description of the qualitative research is provided by Næss (2018).

Besides socio-demographic and travel related variables, the survey collected residential preference indicators, which are central to the analysis on travel-induced residential self-selection integrated in this thesis. Respondents were asked to indicate the importance of 19 items relating to housing and neighborhood characteristics when they were looking for a residential place (or if they were to move to a new dwelling). Each item was measured on a four-point scale from "not at all important" (1) to "highly important" (4). Among the 19 indicators, two are related to transit: proximity to train/metro and proximity to bus/streetcar. They are the travel preference variables of interest in this thesis.

Based on the travel preference variables, consonant and dissonant residents were identified for transit-rich and transit-poor neighborhoods. A statistical analysis of the dissonant and consonant individual in neighborhoods with varying built environment characteristics is combined with the qualitative analysis to investigate the role of travel attitude on residential location choice and travel behavior. A thorough description of the data and method of analysis is presented in Wolday et al. (2018).

4.2.3. Outliers and extreme values

The small-city survey data were examined using standard descriptive statistics and controlled for outliers and extreme values. Left unattended, outliers and extreme values may have a disproportionate influence on statistical estimates and ultimately compromise their validity. As a result, examining the data for outlying values, finding out the source of deviation (whether it is due to error or a legitimate value) and eventually dealing with them in a manner that does not compromise the credibility of the data is important.

The survey data utilized in this thesis are inspected for outliers using the interquartile range analysis, 'Tukey's hinges' as proposed by Hoaglin and Iglewicz (1987). 'Tukey's hinges' are created by multiplying the interquartile range by a multiplier of 2 and then adding the product to the upper quartile to compute the upper boundary and subtract it from the lower quartile to create the lower boundary. Values that fall outside the upper or the lower boundaries are defined as outliers.

The variables for which extreme value analysis is carried out primarily include car driving distance per week and active travel distance per week. In addition to the outright extreme values due to commuting distances that include air travel or reporting errors (four observations in total), four outliers (1 from Drøbak and 3 from Jessheim) were detected on the lower end of the spectrum with 2 or less kilometers driven per week while Kongsvinger has no outliers. For the active travel variable, there were three upper-end outliers in Drøbak with 500 km or more in active travel distance per week, while Jessheim and Kongsvinger have no outliers. The outliers on active travel were treated as extreme values and deleted. In addition to the standard outlier detection method, a sensitivity analysis of statistical estimates was carried out for residential distance exceeding 6 kilometers from the city center to test the robustness of parameters with respect to the outlying settlements.

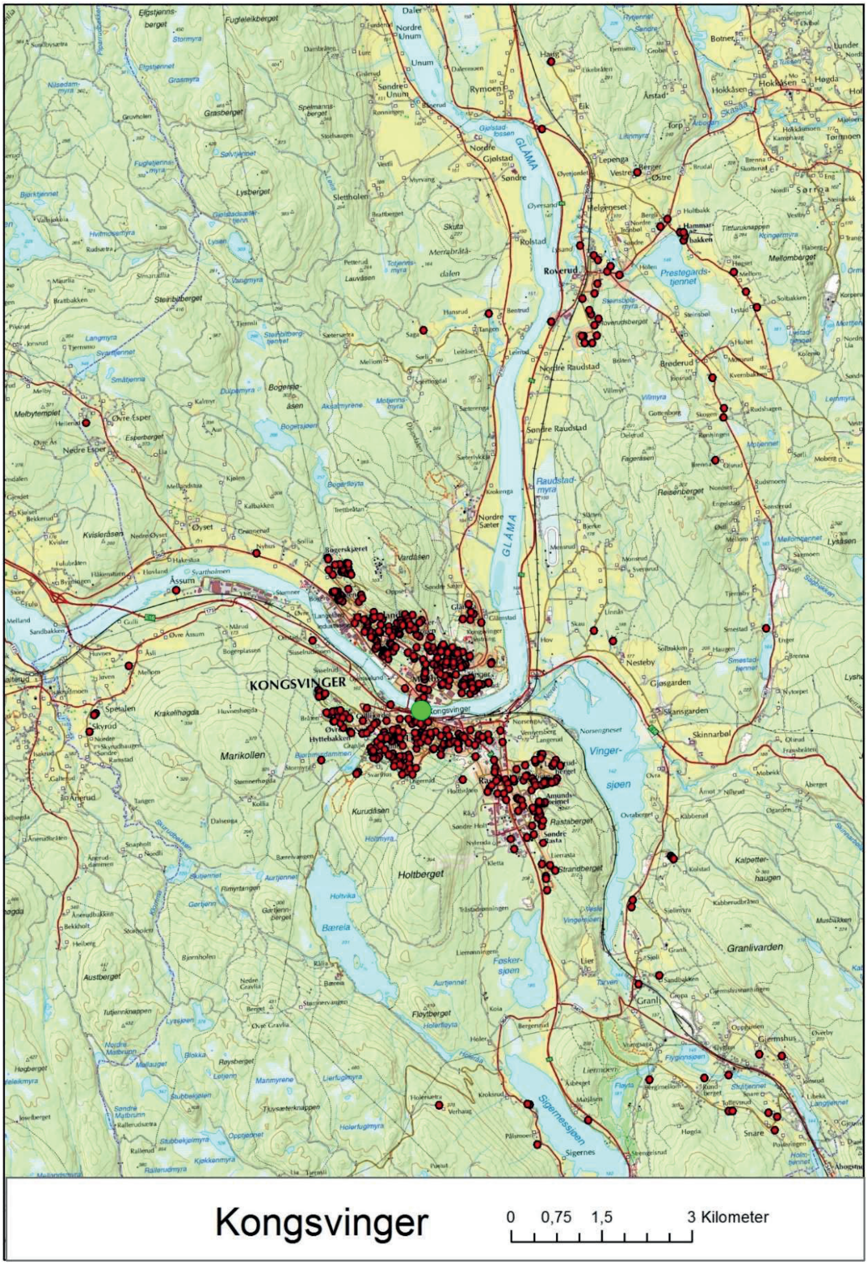
4.3. Geo-coding and secondary data supplements

The data from both surveys is supplemented with register based secondary data and GIS-generated spatial data. The thesis integrates three register based secondary data sources in to the survey data. Population density is derived from geo-coded population register and job density is calculated based on employment register. When computing accessibility by trip purpose, disaggregate data on establishments (facilities) is needed. Here as well, a list of the relevant establishments were obtained from a register based disaggregate and geo-coded data on establishments. The source of the secondary data is Statistics Norway.

In the small-city survey, built environment variables such as residential distance from the city center, population density, job density, accessibility index and street connectivity are generated using Arc GIS. The survey in the Oslo metropolitan region is also supplemented with GIS-generated spatial data.

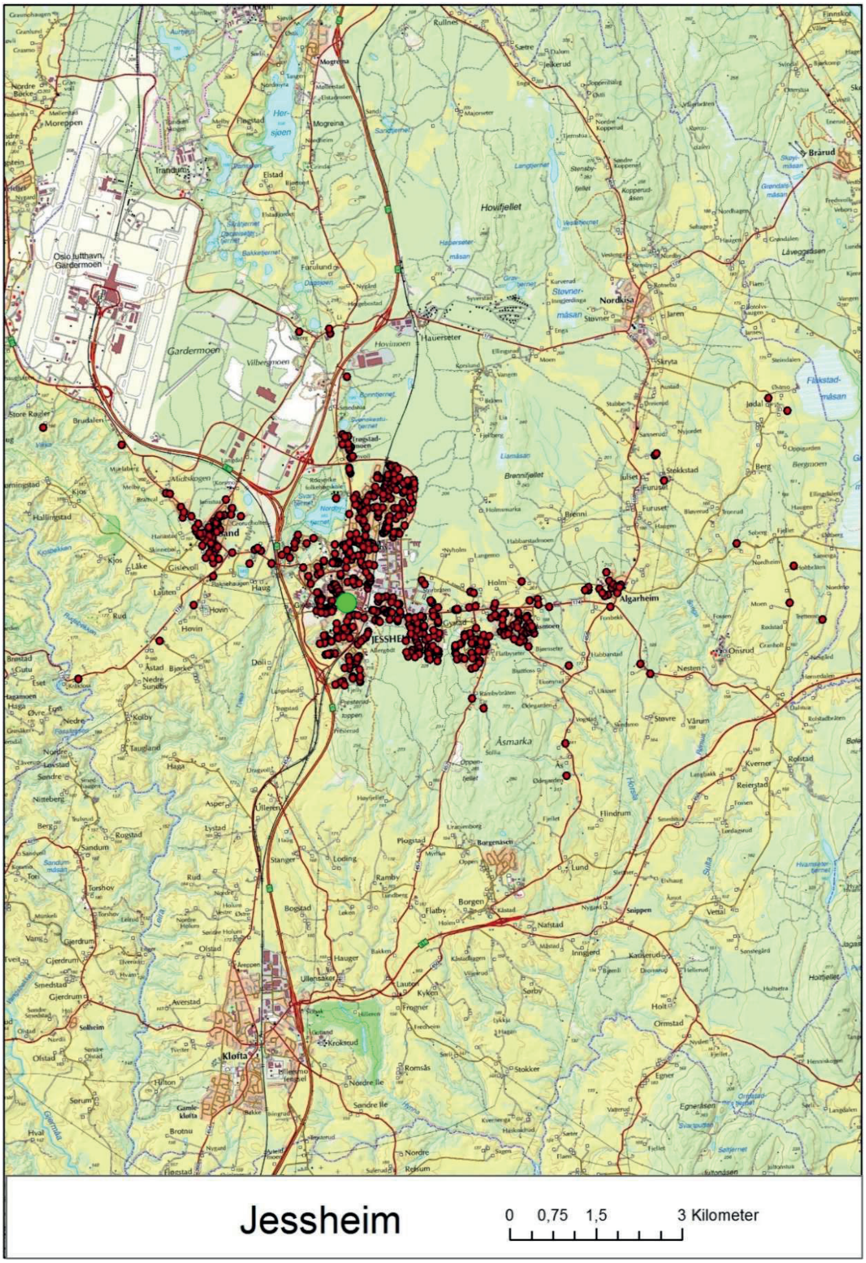
Figure 2. Map of Southern part of Norway and the case cities

Figure 3. Spatial distribution of respondents in the city of Kongsvinger



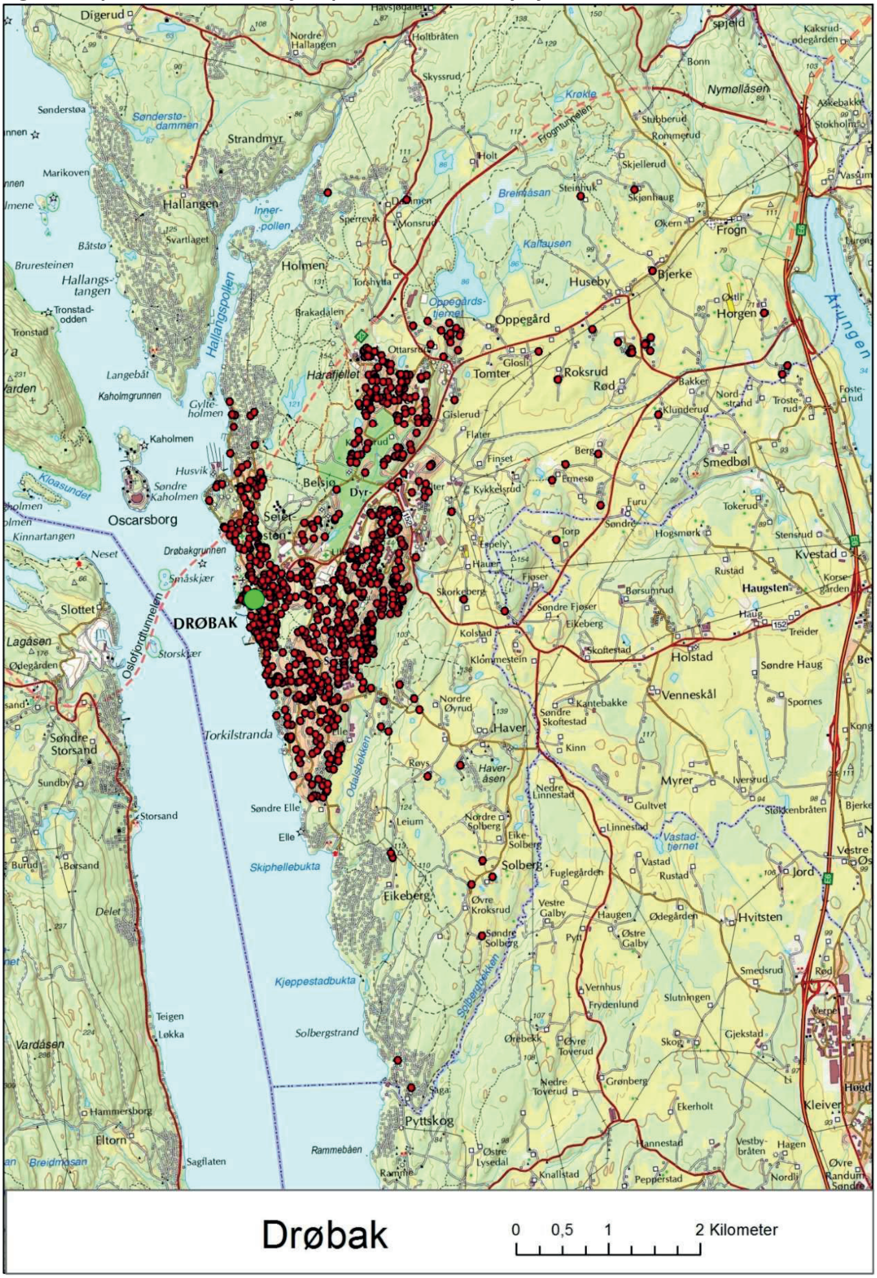
Note: green dote represents the location of the city center

Figure 4. Spatial distribution of respondents in the city of Jessheim



Note: green dote represents the location of the city center

Figure 5. Spatial distribution of respondents in the city of Drøbak



Note: green dotes represent the location of city centers

4.4. Methods

The findings reported in this thesis are obtained from both quantitative and qualitative empirical work. This section provides a short description of the methodological choices made throughout this thesis on concept definitions, measurement of relevant variables and statistical methods adopted. A more detailed account of the specific analytical models used, their methodological prudence and practicality is discussed under each article.

4.4.1. How is travel behavior defined

The main objective of the thesis is to contribute in providing a nuanced understanding of how or rather which built environment variables influence travel behavior in small cities. Travel behavior is the variable of interest to be explained. However, travel behavior is a broad term that can be represented in several ways (travel time, trip frequency, travel mode and travel distance), hence operationalizing it requires a narrower and more precise definition. In the study of small cities, this thesis analyzes two travel behavior variables: car driving distance and trip frequency by non-motorized modes. Car driving distance is measured as the total weekly distance driven in a typical week during the autumn. Driving distance comprises travel to and from work and non-work destination but excludes distance driven in connection with holidays or as part of work e.g. business trips to meetings or customers. Trip frequency by non-motorized modes (biking and walking) is measured as the total number of trips traveled in a typical week during the autumn. Non-motorized trips are measured by trip purpose for a broad spectrum of facilities. As described in section 4.2.1 above, these facilities comprise of grocery stores, medical facilities (medical clinics, dental clinics and pharmacies), restaurants and cafés, facilities for errands other than grocery stores, and fitness centers.

4.4.2. Built environment variables

The main built environment variables included in the analysis of the small cities are classified under three geographic scales. At the neighborhood scale, accessibility to facilities, population density and intersection density are computed. At the local scale (city scale), residential distance from the city center, city center structure, and job density are included. At a regional scale, a centrality variable is defined indicating the regional context of the city.

One of the significant built environment attributes influencing active travel behavior is neighborhood accessibility. Based on distance to facilities, a disaggregate accessibility index was computed for all residential homes in the sample for an area within 805 meters radius (as the crow flies) of the residence.

In order to accommodate the distance decay factor while at the same time accounting for attractiveness, neighborhood accessibility was computed as a weighted index using a gravity model (Hansen 1959; Harris 2001). The accessibility index is then aggregated across facilities to create accessibility indices for center facilities and for grocery stores.

Intersection density, another neighborhood scale variable, is computed as a measure of street network connectivity and is computed as the number of intersections (valence 3 or higher, i.e. at least three way intersections) within a half-mile (805 meters) distance from the residence. The third neighborhood built environment, population density, is calculated as the number of people in 250 by 250 meter grid cells containing the residence.

Residential distance from the city center is calculated along the street network. Job density is measured within 2 km and 5 km distance from the residence. The regional variable, the centrality dummy, is defined based on commuter flow patterns of the resident workforce in each city (table 3 above). The centrality variable assumes the value '1' if a small city employs more than 50 percent of its resident workforce, '0' otherwise.

4.4.3. Analytical models

The analytical models combine both quantitative models and qualitative analysis. The quantitative models comprise of descriptive analysis, component factor analysis, analysis of variance, multiple linear regression, logistic regression and negative binomial regression. The qualitative study included synthesizing and analyzing discursive interviews with 33 interviewees. The objective of the qualitative study is to decode the rationales behind peoples' travel decisions and understand the mechanisms at work.

A summary of the data sources used and the empirical methods utilized in each article is presented in table 4 below.

Table 4. A summary of data and methods in the research papers

	Paper I	Paper II	Paper III	Paper IV
Research objective	Examine the role of travel induced residential self-selection on travel behavior	Investigate the relationship between built environment and driving distance in the context of small cities.	Examine the effect of neighborhood and city-scale built environment variables on active travel	Examining factors that hinder individuals with highly favorable attitude towards active travel from higher walk/bike frequency.
Data source	Survey data and discursive interviews	Survey data collected using a web-based questionnaire in December 2015.	Survey data collected using a web-based questionnaire in December 2015.	Survey data collected using a web-based questionnaire in December 2015.
Data type	Quantitative and qualitative data	Quantitative data	Quantitative data	Quantitative data
Case area	Oslo metropolitan region	Three small cities in the southeastern part of Norway (Kongsvinger, Jessheim and Drøbak)	Three small cities in the southeastern part of Norway (Kongsvinger, Jessheim and Drøbak)	Three small cities in the southeastern part of Norway (Kongsvinger, Jessheim and Drøbak)
number of observations	1992 observations and 17 interviewees	Kongsvinger (N=361), Jessheim (N=437), Drøbak (N=595)	Kongsvinger (N=365), Jessheim (N=522), Drøbak (N=733)	889 (all three cities pooled together)
Model specification	-Descriptive statistics (preference ranking) -Analysis of variance (one way ANOVA with post hoc tests) -Logistic regression-Qualitative analysis	-Component factor analysis -Multiple linear regression -logistic regression	-Negative binomial regression -One way ANOVA with post hoc test	-Descriptive statistics (preference ranking) -Component factor analysis -One way ANOVA with post hoc tests) -Logistic regression

Travel behavior	Commuting trip frequency by transit and non-work trip frequency by transit	-Car driving distance-Likelihood of commuting by train is addressed in a limited capacity in conjunction with car driving distance.	Trip frequency by non-motorized modes (walking and biking) to non-work destinations	Trip frequency by non-motorized modes (walking and biking) to non-work destinations
Unit of analysis	Individual traveler/trip maker denominated as consonant or dissonant resident in a transit-poor or transit-rich neighborhood	The individual trip maker (person). The analysis includes all respondents in the sample.	The individual trip maker (person). The analysis includes all respondents in the sample.	The individual trip maker (person) with high positive attitude towards active travel. Individuals with high positive attitude towards active travel are further grouped in to those with above median trip frequency (**high-active-transport consonant**) and those with below median trip frequency (**low-active-transport dissonant**).
Independent variables	Residential preference indicators (a set of 19 Likert items) including built-environment factors (proximity to transit), demographics (age, household size, number of children, gender) and socio-economic variables (income, education employment) and driver's license. - Explanatory qualitative analysis on the influence of built environment (e.g. residential distance from the city center and other facilities, transit access, etc.) on travel.	Five factor components summarizing the underlying clusters in 15 residential preferences, demographics (age, household size, number of children, gender) and socio-economic variables (income, education employment), built environment attributes (residential distance from the city center, job density and population density) and regional context (centrality dummy).	Neighborhood built environment factors (population density, accessibility index, intersection density), city-scale built environment (residential distance from the city center), demographics (household size, gender, age, number of children), socio-economics (education, income and employment), topography, car-access and attitude towards active travel.	Two factor variables (walk/bike path characteristics and destination accessibility) summarizing the dimensions of 7 Likert items perceived to increase the likelihood of active travel, socio-demographic variables (age, gender, income, education, employment), built environment variables (residential distance from the city center, Accessibility index by trip purpose, intersection density), topography, car availability and city dummy.

5. Article summary

To state the obvious, transportation is demanded largely as an instrumental service to connect spatially separated facilities (land-use types) at which people want to engage in activities. The spatial separation (i.e. distance between various land-use types) and the transportation challenges/options it presents are likely to vary between cities of different sizes. Despite large and growing literature in land-use and transportation planning, the focus has predominantly been on medium to large cities. This thesis focuses on small cities and by way of the following four articles, it strives to make a humble contribution to the literature of urban planning in small cities. The first article focuses on how travel related attitudes are perceived in modeling the relationship between built environment and travel behavior and hence serves as a methodological precursor to the remaining three articles. The second article focuses on the relationship between built environment and car diving distance whereas the last two articles address the relationship between built environment at the local scale and active transport.

5.1. Article I

The debate on whether manipulating built environment can cause individuals to change their travel behavior is largely settled. The debate on the extent of influence built environment has on travel behavior, however, is still lingering and consensus has been elusive. Central to this debate is the issue of travel induced-residential self-selection; people's tendency to choose their place of residence based on their travel preference. This article addresses the issue of travel-induced residential self-selection by addressing its underlying assumptions.

Using a combination of quantitative and qualitative analysis on data collected from the Oslo metropolitan region in 2015, the study attempted to answer three interrelated research questions: (1) How important is transit preference in residential location choice? (2) Which factors cause transit-preferring people to live in areas with poor access to transit? (3) How do transit preference and transit access factor into transit use?

As part of the quantitative analysis, first, individuals' preference to transit were matched with their neighborhood typologies resulting in the distinction between consonant and dissonant individuals residing in two neighborhood typologies (transit-rich and transit-poor neighborhoods). Then, employing preference ranking, logistic regression and ANOVA tests, the research found that transit preference, while relevant for residential location choice, is more so as second tier after other more important preferences related to lifecycle/demographics are satisfied. Individuals with simultaneously high preference for transit and low preference for attributes related to households with children are likely to reside in transit-friendly neighborhoods. Furthermore, individuals who prefer transit but live in transit-poor zones tend to have higher preference for private garden, a larger number of children, lower income, and are older. Variations in access to transit and variation in transit preference are also shown to have significant influence on transit use.

Results of qualitative interviews are consistent with these findings and give more credence to the statistical findings by elaborating the mechanism by which the built environment and travel preference affect residential and travel choices.

This article serves as a methodological precursor for the succeeding three articles and contributes in reducing methodological ambiguity regarding residential self-selection by guiding towards appropriate model specification.

5.2. Article II

This article explores the association between built environment characteristics and car driving distance in a small city context, and whether there is a local and/or regional dimension to that association.

Residential distance from the city center is an important built environment variable in this and the succeeding two articles. The residence is the base where daily life is planned, travel scheduled, family life organized and not least, it is the origin and ultimate destination of most of daily travel activities. Likewise, the city center, by providing the highest concentration of facilities in the urban space (at least in monocentric cities), presumably, establishes itself as a highly attractive destination. The distance of residences from the city center, therefore, brings together the two important aspects of travel activity (the origin and destination) and becomes an important construct in understanding the effect of built environment on travel behavior.

Three interrelated questions are addressed in this article. First, does residential distance from the city center significantly influence car driving distance in a small city context after accounting for differences in demographics, socio-economic attributes and residential preferences? Questions pertaining to the effect of socio-economic and demographic attributes on travel behavior while controlling for residential distance from the city center are also addressed here. Second, do neighborhood built environment factors influence car driving distance after accounting for differences in residential distance from the city center, socio-economic variables and demographic attributes? Third, how important are neighborhood and city-scale built environment factors in influencing total driving distance in the context of regional influence?

Logistic and linear regression models are applied on survey data from three small cities, Kongsvinger, Jessheim and Drøbak. The results underscore that regional context is an important denominator on how and to what extent the influence of residential location is reflected on travel behavior in a small city context. In a city such as Kongsvinger, where regional pull-factors from a nearby higher-order city is weaker, proximity to the center of the small city significantly reduces total car driving distance. In cities with proximity to a higher-order city, the influence of distance from the city center on driving distance is weaker and likely mediated by transit commutes.

Among the demographic and socio-economic characteristics, gender has consistently strong influence on car driving distance whereas income and employment are strongest where regional characteristics are influential.

Article two dealt with the relationship between built environment and car driving distance. To give a nuanced account of how built environment influences travel behavior, travel by non-motorized transport (often referred to as active transport) also has to be addressed. Articles three and four explore the effects on non-motorized travel of relevant local built environment factors such as accessibility to and dispersal of facilities as well as design features such as street network on active transport behavior in small cities.

5.3. Article III

Article three set out three research objectives: First, to identify built environment characteristics with significant influences on active transport. Second, to explore the effect of travel attitude on active transport. This part also addresses possible interactions between travel attitudes and built environment in influencing travel behaviour. Third, to explore the implication of variations in city centre structures and the resulting distribution of facilities on active transport.

Applying negative binomial regression, descriptive statistics and ANOVA test on survey data from three Norwegian small cities (Kongsvinger, Jessheim and Drøbak), the analysis finds attitude towards active travel to exert the strongest influence on the propensity to bike/walk. As Handy (2015) noted, when other means of travel is available, the decision to walk or bike depends, largely, on the motivation to do so. Neighbourhood-scale accessibility is also important but its influence varies by trip purpose (facility type). For trips to grocery stores, neighbourhood scale accessibility is highly influential whereas for centre facilities centralization (concentration of facilities at the city centre) is more strongly associated with walk/bike frequency. Topography (e.g. hilly neighbourhoods) also reduces the likelihood of traveling by active modes, irrespective of destination type.

5.4. Article IV

Findings in the third article show that the motivation towards active travel has a strong influence on the decision to travel by active transport. However, the literature also shows that there is a significant variation in walk/bike trip frequency among individuals with highly positive attitude to active transport. Article four, using survey data from three small cities, explores factors that characterize individuals with high positive attitude towards active transport and attempts to answer the following questions: Which factors are likely to cause low levels of active transport among high-positive-attitude individuals? And, can changes in certain neighborhood built environment factors (e.g. walk/bike path characteristics) get dissonant[20] individuals to increase their active transport magnitude?

Using a combination of descriptive and binary logistic analysis, this paper finds that low average accessibility to non-work facilities, residential distance from the city center, topography, car access, family size, and employment are associated with low-active-transport dissonance. Accessibility to neighborhood facilities and proximity to the city center are the two most influential variables that increase the likelihood of higher walk/bike rates among individuals with high positive attitude to active transport but who travel below median levels by active transport. Employment and large family size, on the other hand, tend to cause individuals to be dissonant. Neighborhood design factors related to walk/bike paths do not influence walk/bike rates of dissonant residents more than they do for consonant residents, as they are almost equally important to both categories of individuals.

An analysis of walk/bike trips by trip purpose shows that the effect of built environment factors on the likelihood of being low-active-transport dissonant varies by facility category. For trips to grocery stores, neighborhood accessibility is the most influential variable. For center facilities, although the neighborhood accessibility index is also important, proximity to the city center exerts the strongest influence.

[20] Dissonant individuals refers here to individuals with high-positive-attitude to active transport but performing low (below median) levels of active travel.

6. Synthesizing discussion

6.1. Introduction

This section summarizes the overall research exercise of the project. First, I will briefly discuss the research premise of the project on why a separate focus on small cities is necessary followed by the research questions. Next, the methodology chosen to satisfactorily and coherently answer the research questions are presented. Limitations or weaknesses in the thesis, contribution to the body of knowledge, and recommendations to practice are presented in the final section.

6.2. Research premise and motivation

Geographic scale of analysis is critical in modeling associations between variables that have to do with space. Being incognizant to scale of analysis was one of the main causes of incoherent and conflicting results in the early years of research on land-use and transportation relationship. Current research is mostly well aware of and therefore properly addresses two of the early scale related challenges: the modifiable areal unit problem (MAUP) and the unidentifiable geographic context problem (UGCoP) (Kwan 2012a; Kwan 2012b).

A third dimension associated with geographic context, which is slightly different and rarely addressed, relates to scale/size differences between cities as units of geographic context. City size influences the extent of specialization and diversity of services in a city to a large degree, which in return can have significant implications for travel patterns. Consequently, the extent of influence of identically defined built environment variables such as land-use mix, density, distance to public transport, etc. on travel behavior is likely to differ significantly between small and larger cities. Failing to consider this can compromise the external validity of a study and lead to false assessment of the transferability of research findings outside the research environment.

The significance of differences in city size for the relationship between land-use and travel behavior is widely recognized among scholars. Yet, little attention has been paid to understanding the relationship between urban structure and travel behavior in smaller cities. Besides the robust theoretical basis for a separate focus on smaller cities (that findings from larger cities may not be applicable), a sizable share of national populations also live in small cities. In Norway, for example, small cities are home to over a quarter of the population[21].

The aim of this thesis has been to explore the relationship between built environment and travel behavior in a small-city context. The overarching research question of the thesis was: which built environment attributes and transport strategies can best serve the goal of sustainable mobility? In addressing this main question, a number of researchable questions are formulated and an attempt to answer them is made in the four articles attached as part of the thesis.

6.3. Methodology and empirical analysis

6.3.1. Methodology

The methodological choice adopted in this thesis is informed by critical realist ontological and epistemological thought. For critical realism, reality exists independent of our knowledge of it. An effort to uncover causal patterns is therefore about searching beyond observable regularities. Four concepts are central to understanding how causality is conceived in critical realism: structures, powers, generative mechanisms and tendencies. Structures (e.g. built environment, but also entities such as organizations, legislation, and the psychological properties of humans), by their nature, possess causal powers. The causal powers, however, are not always active and therefore a generative mechanism needs to be triggered for the causal powers to be exercised. Causality is, therefore, understood as tendency, the potential to exert causal influence when triggered. Even when triggered, the outcome is unlikely to be the same every time a mechanism is triggered as other incidental and contextual mechanisms are likely to be simultaneously acting out.

Knowledge generation (establishing causal relationships between events), in the critical realist epistemology is about uncovering the inner working at play in bringing about a certain event or outcome. In line with this understanding, this thesis applies a combination of quantitative and qualitative methods to ascertain causal relationship, although the main part of its empirical work is within the quantitative domain. The qualitative analysis explores the mechanisms that connect the cause and the effect, which then informs the quantitative models in outlining the observed regularities between the cause and effect.

[21] The proportion the Norwegian population who live in small cities with inhabitants ranging between 3 000 and 30 000 is about 28% (Statistics Norway, 2015).

I have also drawn lessons from my involvement in another thematically related research project (RESACTRA[22]) that immensely benefitted this thesis. The RESACTRA project applied elaborate qualitative and quantitative methods in addressing the relationship between built environment and travel behavior in two metropolitan regions in Norway (Cao et al. 2018; Næss et al. 2017; Wolday et al. 2018), and the appropriate methodology to investigate that relationship (Næss 2018; Wolday et al. 2018). My involvement from research design to execution (interviewing, interpreting and synthesizing qualitative interviews), and carrying out qualitative and quantitative analysis gave me valuable insights on people's rationales about their residential preferences and travel choices. This again helped inform the methodological choices in this thesis.

6.3.2. Empirical analysis and results

The four articles fall under three main research themes. The aim of the first research theme is to investigate the significance of travel attitude as a source of bias in land-use and transportation research. Its purpose in the thesis is to inform the succeeding two research themes on how to model travel attitudes in travel behavior research. The second research theme addresses neighborhood, local (city scale) and regional built environment attributes that influence car driving distance in a small city context. The third research theme focuses on active transport and investigates the relationship between built environment at neighborhood as well as city scale that influence active transport behavior in small cities. From the idiosyncratic characteristics, the role of attitude towards active transport is given special attention in the last theme. In modeling active transport, travel attitude is included not as a control variable but as a variable of prime interest due to its direct effect on motivation to active transport. The modeling choice is inspired by ecological models and informed by lessons from the first research theme.

In large cities, the relationship between residential distance from the city center and travel behavior presents one of the most compelling arguments for compact urban development. Given the contextual nature of the relationship between built environment and travel behavior, however, can we claim, with the same level of confidence as in larger cities, that compact development in and around the central areas of small cities can contribute to sustainable mobility? More precisely, which built environment attributes and land-use strategies are likely to lead to sustainable mobility in the case of small cities? These are two central questions and by way of the articles, this thesis addresses the second question

[22] A project about residential location, activity participation and travel behavior with surveys and qualitative interviews in metropolitan regions of Oslo and Stavanger. The project was financed by the Norwegian Research Council, had a 3.5 years span and ended in June of 2017.

and reflects on the first. Articles II, III, and IV analyze the effect of built environment at various geographic scale on car driving distance and active transport. The main findings reinforce each other.

At the local scale, proximity to the city center (in a monocentric small city) reduces travel distance by car and increases the likelihood of commuting by transit. Hence, densification in and close to the city center can contribute to reducing car driving distance. These findings (from article II), although informative, addressed the issue of planning towards sustainable mobility in small cities only partially, as they only focus on one mode, the car.

Car-use may be reduced by promoting a modal split that takes travelers away from cars to transit and/or non-motorized modes. Small cities lack scale economies in providing a reliable and frequent public transit. As a result, public transit cannot be relied upon to efficiently substitute car-use. On the other hand, the inherent physical characteristics of small cities give non-motorized transport a formidable potential as an alternative mode for local travel. Small cities are largely characterized by relatively compact (short distance from the center to the edge of the city) and predominantly monocentric city configurations, which together create an urban environment that is reachable by non-motorized transport. Commercial and personal services as well as institutional facilities are often concentrated at small-city centers. This in turn reduces the average distance from residential settlements to various facilities, making the city center a potential destination that is better accessible by active modes.

Overall, the sustainability potential of small cities lies in fostering travel by active modes. Hence, the effect of relevant local built environment factors such as accessibility to and dispersal of facilities as well as design features such as street network on active transport have to be explored to give a more nuanced answer about the effect of built environment on travel behavior in small cities.

Articles three and four explore the relationship between built environment and active transport behavior in small cities. Both articles reach coherent sets of conclusions. The empirical analysis found that accessibility and attitudes to active transport are among the most influential variables. Although the effect of dispersal of facilities away from the city center varies by facility type, generally, proximity to the city center is associated with higher average accessibility, which significantly increases transportation by active modes. For grocery facilities, accessibility at neighborhood scale is most influential whereas for center facilities[23] proximity to the city center is the most influential built

[23] Center facilities comprise of facilities for errands other than grocery stores, cafés and restaurants and medical clinics.

environment attribute. Besides, dispersal of center facilities away from the city center reduces active transport magnitudes significantly.

Four main conclusion with implications for policy can be drawn from this thesis. First, in answering the question raised previously regarding whether densification can be a viable planning tool for sustainable mobility in small cities, the answer is a cautious yes. Yes, because of the evidence presented above, but cautious, because the social and economic viability of such an endeavor have yet to be explored.

Second, planners should avoid measures that lead to sprawling of centre facilities, for example, commercial land-uses such shopping centres at city fringes. Third, since grocery stores that are accessible at a neighbourhood scale increase the propensity of active travel, planners should reflect on new residential developments in such a way that these developments support basic neighbourhood facilities such as grocery stores.

Fourth, the analysis also reveals that attitude towards active travel exerts strong influence on people's tendency to travel by non-motorized modes. Therefore, awareness campaigns to sway individual and community attitudes coupled, for example, with incentives to the adoption of electric bikes in order to reduce the level of exertion associated with topographical contours may likely boost walk/bike frequency.

6.4. Limitations

Data on non-motorized transport combines walking and biking trips together. Lumping up biking and walking together and treating them as though they are a single mode may lead to a limitation known as unidentified geographic context problem or in short UGCoP (Kwan & Weber 2008; Kwan 2012b), a bias associated with arbitrarily identifying the effective zones of a travel mode. Since biking and cycling have different effective geographic zones at which built environment variables are expected to influence walking/biking behavior (Forsyth & Krizek 2011; Gehrke & Clifton 2014; Nielsen et al. 2013; Nielsen & Skov-Petersen 2018), combining walking/biking transport data may miss some important nuances in the analysis of non-motorized travel behavior.

On the bright side, the neighbourhood characteristics that influence both modes are largely similar. Moreover, the number of walking trips greatly surpasses biking trips. The Norwegian average for smaller cities shows that walking accounts for about 81 per cent of active travel trips according the recent National Travel Survey from 2013/2014. Given that the aim of this thesis is to identify influential built environment attributes on active travel in a multivariate regression setting, I maintain that combining both biking and walking will not be a major source of bias.

Another limitation, also related to geographic context, pertains to the delimitation of a half-mile accessibility range, which is more appropriate for walking than for cycling. Moreover, pedestrian and cyclist shortcuts and paths are not included as routes. I believe, however, this limitation will not have significant bias, as the block sizes in the three investigated small cities are generally small with human-scale proportions between intersections.

6.5. Contributions to the state of knowledge

This thesis makes a humble contribution on four areas. First, by putting the spotlight on smaller cities. The main purpose of this thesis is to highlight the relationship between built environment and travel behavior in the context of small cities. Geographic context is an important denominator in understanding how land-use influences peoples' travel behavior. However, research on land-use and travel behavior almost exclusively focus on medium to large cities while small cities barely get the attention. This study, by focusing on cities with population size of 10 000 to 20 000 inhabitants, intends to contribute in filling this literature gap and inform small-city planners on built-environment factors that are influential at that geographic scale.

Second, by conceptualizing the role of attitude towards active travel on travel behavior. When modeling the effect of built environment on travel behavior, travel attitude is often seen as confounding that relationship via its perceived influence on residential location choice. This thesis argues that travel attitude, through its influence on the motivation to travel by active modes, directly affects travel behavior. Attitude towards active travel is a strong indicator of an individual's motivation to travel actively. Therefore, travel attitude, especially when modeling non-motorized travel, should be modeled as a factor with direct effect and of direct policy relevance, and not as a control variable to purge off biases (due to travel-induced residential self-selection). The understanding that attitude to active travel is an important factor with direct influence on travel behavior is not new. In fact, highlights in conceptualizing active travel by Handy (2015) and a longstanding modeling approach in health sciences, known as ecological models (Sallis et al. 2004; Sallis et al. 2006), solidify how important travel attitude is in the decision to travel actively. Nonetheless, to my knowledge, these models have not been evaluated in relation to travel induced residential self-selection.

Third, using the consonant and dissonant categorization of individual travelers, this study highlights factors that lead to differentials in active travel magnitude among people with high positive attitude towards active travel. Besides socio-economic, demographic and built environment characteristics, active travel magnitudes depend on whether a person is motivated to walk/bike (Handy 2010; Handy 2015). As Handy (2015) postulated, without motivation, an individual is unlikely to engage in active travel unless that is the only option available. Given this strong influence of attitude towards active travel on active travel outcomes, various studies incorporate attitude in their studies either as control variables to purge off confounding influences from built environment factors or in appreciation of the direct influence attitude has on travel behavior. Either way, to this author's knowledge, investigating factors leading to differential in active travel magnitudes among individuals perceived to be motivated to walk/bike (individuals with high positive attitude towards active travel) has not been attempted earlier.

The dichotomous categorization of individuals into dissonant and consonant groups is inspired by Schwanen and Mokhtarian (2004) seminal work on the subject. In defining the consonant and dissonant residents, Schwanen and Mokhtarian (2004) matched individual attitudes with their neighborhood characteristics. In this paper, a slightly different definition is adopted. Instead of defining consonant and dissonant residents based on how individual attitudes match or mismatch their residential characteristics, individual's attitudes are matched with their active travel magnitudes. This categorization is especially useful in understanding the separate effect of socio-demographic and built-environment factors on travel behavior differentials when the motivation to travel actively is not an issue. Furthermore, instead of taking the whole spectrum of attitude levels, I took only the high end of the spectrum. This led to only two groups instead of the more commonly used 2 X 2 classification (Cao 2015; Wolday et al. 2018).

Fourth, distinguishing between facility categories when modeling the effect of built environment on travel by active modes. This is important because the degree of specialization between facilities on the one hand and the average trip frequency a customer needs to make to a facility on the other determine the likely location of a facility in the urban space. Those with higher product diversification and providing specialized products tend to gain more from agglomeration and hence are likely to choose central locations. Conversely, firms providing less diversified goods and services (e.g. grocery stores) may not gain as much from agglomeration. Another aspect influencing firms' location decisions is the average trip frequency a person needs to make to a facility. Higher expected trip frequency per person means that the minimum threshold of potential customers is satisfied within a narrower range, to borrow Christaller's formulation (Christaller 1966). Facilities with higher expected trip frequency are likely to locate in and around residential neighborhoods whereas those with low expected trip frequency require a larger catchment area and therefore are likely to choose a central location. The implication of such distinction between the facilities is to inform planners on the ideal land-use planning to achieve sustainable mobility, e.g. centralization/decentralization of which facilities is likely to lead-to higher rates of active travel?

References

Aguilera, A. & Mignot, D. (2004). Urban Sprawl, polycentrism and commuting. A comparison of Seven French Urban Areas. 1: 93-113.

Amundsen, B. & Lie, E. (2013). Fewer willing to participate in surveys. *Forskning magazine: 2/2013*, Forskning magazine no 2/2013 (2/2013).

Aguilera, A. & Mignot, D. (2004). Urban Sprawl, polycentrism and commuting. A comparison of Seven French Urban Areas. 1: 93-113.

Amundsen, B. & Lie, E. (2013). Fewer willing to participate in surveys. *Forskning magazine: 2/2013*, Forskning magazine no 2/2013 (2/2013).

Bhaskar, R. (2008). *A realist theory of science*. Classical texts in critical realism. London ; New York: Routledge. xxv, 284 p. pp.

Bhat, C. R. & Koppelman, F. S. (1999). Activity-Based Modeling of Travel Demand. In Hall, R. W. (ed.) *Handbook of Transportation Science*, pp. 35-61. Boston, MA: Springer US.

Bhat, C. R. & Guo, J. Y. (2007). A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. *Transportation Research Part B: Methodological*, 41 (5): 506-526.

Boarnet, M. & Crane, R. (2001). *Travel by design: the influence of urban form on travel*. Oxford: Oxford University Press. 1 online resource (x, 224 s.) : ill pp.

Cao, J., Næss, P. & Wolday, F. (2017). Urban containment and inner-city densification reduce auto ownership. *Urban Studies* (forthcoming).

Cao, J., Næss, P. & Wolday, F. (2018). Examining the effects of the built environment on auto ownership in two Norwegian urban regions (under review).

Cao, X. (2008). Is Alternative Development Undersupplied? Examination of Residential Preferences and Choices of Northern California Movers. *Transportation Research Record: Journal of the Transportation Research Board*, 2077: 97-105.

Cao, X., Mokhtarian, P. L. & Handy, S. L. (2009a). Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Empirical Findings. *Transport Reviews*, 29 (3): 359-395.

Cao, X., Mokhtarian, P. L. & Handy, S. L. (2009b). No particular place to go: an empirical analysis of travel for the sake of travel. *Environment and Behavior*, 41 (2): 233-257.

Cao, X., Mokhtarian, P. L. & Handy, S. L. (2009c). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A*, 43 (5): 548-559.

Cao, X. (2015). Heterogeneous effects of neighborhood type on commute mode choice: An exploration of residential dissonance in the Twin Cities. *Journal of Transport Geography*, 48: 188.

Cao, X. & Chatman, D. (2016). How will smart growth land-use policies affect travel? A theoretical discussion on the importance of residential sorting. *Environment and Planning B: Planning and Design*, 43 (1): 58-73.

Cervero, R. (1984). Managing the Traffic Impacts of Suburban Office Growth, 38 Transp. *Q*, 533: 540-49.

Cervero, R. (1986). Unlocking Suburban Gridlock. *Journal of the American Planning Association*, 52 (4): 389-406.

Cervero, R. (1989). Land-use mixing and suburban mobility.

Cervero, R. & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, 2 (3): 199-219.

Cervero, R. & Wu, K.-L. (1997). Polycentrism, commuting, and residential location in the San Francisco Bay area. *Environment and Planning A*, 29 (5): 865-886.

Chapin, F. S. (1971). Free Time Activities and Quality of Urban Life. *Journal of the American Institute of Planners*, 37 (6): 411-417.

Chatman, D. G. (2014). Estimating the effect of land use and transportation planning on travel patterns: Three problems in controlling for residential self-selection. *Journal of Transport and Land Use; Vol 7, No 3 (2014)*.
Christaller, W. (1966). *Central places in southern Germany*. Englewood Cliffs, N.J.: Prentice-Hall. 230 s. : ill. pp.
Crane, R. & Crepeau, R. (1998). Does neighborhood design influence travel?: A behavioral analysis of travel diary and GIS data. *Transportation Research Part D: Transport and Environment*, 3 (4): 225-238.
Crane, R. D. & Chatman, D. G. (2003). *Traffic and Sprawl: Evidence from U.S. Commuting, 1985 To 1997*.
Crozet, Y. (2012). The Three Stages of Accessibility: The Coming Challenge of Urban Mobility. In *Sustainable Transport for Chinese Cities*, pp. 79-97.
Cullen, I. & Godson, V. (1975). Urban networks: The structure of activity patterns. *Progress in Planning*, 4: 1-96.
Dalvi, M. & Martin, K. (1976). The measurement of accessibility: Some preliminary results. *Transportation*, 5 (1): 17-42.
Danermark, B., Ekstrom, M., Liselott, J. & Karlsson, J. C. (2002). *Explaining society : critical realism in the social sciences*. London ; New York: Routledge. 221 p. pp.
Daniels, R. & Mulley, C. (2013). Explaining walking distance to public transport: The dominance of public transport supply. *2013*, 6 (2): 16.
Dijst, M. (1999). Action space as planning concept in spatial planning. *Netherlands journal of housing and the built environment*, 14 (2): 163-182.
Dijst, M. & Vidakovic, V. (2000). Travel time ratio: the key factor of spatial reach. *Transportation*, 27 (2): 179-199.
Ettema, D. & Nieuwenhuis, R. (2017). Residential self-selection and travel behaviour: What are the effects of attitudes, reasons for location choice and the built environment? *Journal of Transport Geography*, 59: 146-155.
European Union. (2001). Strategy For Integrating Environment And Sustainable Development Into The Transport Policy (the April Resolution). Luxembourg: European Union's Council of Ministers.
Ewing, R. & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record: Journal of the Transportation Research Board*, 1780: 87-114.
Ewing, R. & Handy, S. (2009). Measuring the unmeasurable: Urban design qualities related to walkability. *Journal of Urban design*, 14 (1): 65-84.
Ewing, R. & Cervero, R. (2010). Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association*, 76 (3): 265-294.
Ewing, R., Tian, G., Goates, J. P., Zhang, M., Greenwald, M. J., Joyce, A., Kircher, J. & Greene, W. (2014). Varying influences of the built environment on household travel in 15 diverse regions of the United States. *Urban Studies*, 52 (13): 2330-2348.
Filion, P., Bunting, T. & Warriner, K. (1999). The Entrenchment of Urban Dispersion: Residential Preferences and Location Patterns in the Dispersed City. *Urban Studies*, 36 (8): 1317-1347.
Fleetwood, S. (2017). The critical realist conception of open and closed systems. *Journal of Economic Methodology*, 24 (1): 41-68.
Forsyth, A. & Krizek, K. (2011). Urban Design: Is there a Distinctive View from the Bicycle? *Journal of Urban Design*, 16 (4): 531-549.
Gehrke, S. & Clifton, K. (2014). Operationalizing Land Use Diversity at Varying Geographic Scales and Its Connection to Mode Choice. *Transportation Research Record: Journal of the Transportation Research Board*, 2453: 128-136.
Gordon, P., Kumar, A. & Richardson, H. W. (1989). The influence of metropolitan spatial structure on commuting time. *Journal of Urban Economics*, 26 (2): 138-151.

Gordon, P., Richardson, H. W. & Jun, M.-J. (1991). The Commuting Paradox Evidence from the Top Twenty. *Journal of the American Planning Association*, 57 (4): 416-420.
Gordon, P. & Lee, B. (2015). Spatial structure and travel: trends in commuting and non-commuting travels in US metropolitan areas. In. Cheltenham, UK: 'Edward Elgar Publishing, Inc.'.
Grunfelder, J. & Nielsen, T. S. (2012). Commuting behaviour and urban form: a longitudinal study of a polycentric urban region in Denmark. *Geografisk Tidsskrift-Danish Journal of Geography*, 112 (1): 2-14.
Guerra, E. & Cervero, R. (2013). Is a Half-Mile Circle the Right Standard for TODs?
Guo, J. Y. & Bhat, C. R. (2007). Operationalizing the concept of neighborhood: Application to residential location choice analysis. *Journal of Transport Geography*, 15 (1): 31-45.
Handy, S. (1996). Urban Form and Pedestrian Choices: Study of Austin Neighborhoods. *Transportation Research Record: Journal of the Transportation Research Board*, 1552: 135-144.
Handy, S., Cao, X. & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment*, 10 (6): 427-444.
Handy, S. (2010). Walking, bicycling, and health. In Malekafzali, S. (ed.) *Healthy, Equitable Transportation Policy*. Oakland, CA: PolicyLink.
Handy, S., Xing, Y. & Buehler, T. (2010). Factors associated with bicycle ownership and use: a study of six small U.S. cities. *Transportation*, 37 (6): 967-985.
Handy, S. (2015). Community design and active travel. In Hickman, R., Givoni, M., David, B. & Banister, D. (eds) *Handbook on Transport and Development* Cheltenham, UK: Edward Elgar Publishing.
Handy, S. (2017). Thoughts on the Meaning of Mark Stevens's Meta-Analysis. *Journal of the American Planning Association*, 83 (1): 26-28.
Hansen, W. G. (1959). How Accessibility Shapes Land Use. *Journal of the American Institute of Planners*, 25 (2): 73-76.
Hanson, S. (1980). Spatial diversification and multipurpose travel: implications for choice theory. *Geographical Analysis*, 12 (3): 245-257.
Harris, B. (2001). Accessibility: Concepts and Applications. *Journal of Transportation and Statistics*, 4 (2/3): 15-30.
Hess, D. B. (2009). Access to Public Transit and Its Influence on Ridership for Older Adults in Two U.S. Cities. *2009*, 2 (1).
Hickman, R. & Banister, D. (2015). New household location and the commute to work: changes over time. In. Cheltenham, UK: 'Edward Elgar Publishing, Inc.'.
Hjorthol, R., Engebretsen, Ø. & Uteng, T. P. (2014). The Norwegian Travel Survey 2013/14 – key results (in Norwegian language), https://www.toi.no/getfile.php?mmfileid=39511. Oslo: Norwegian Center for Transport Research: TØI Report 1383/2014. 140 pp.
Hoaglin, D. C. & Iglewicz, B. (1987). Fine-Tuning Some Resistant Rules for Outlier Labeling. *Journal of the American Statistical Association*, 82 (400): 1147-1149.
Holden, E. (2001). *Boligen som grunnlag for bærekraftig forbruk*. Trondheim: Norges teknisk-naturvitenskapelige universitetltet, Institutt for by- og regionplanlegging.
Hong, J., Shen, Q. & Zhang, L. (2014). How do built-environment factors affect travel behavior? A spatial analysis at different geographic scales. *Transportation*, 41 (3): 419-440.
Hu, H., Xu, J., Shen, Q., Shi, F. & Chen, Y. (2018). Travel mode choices in small cities of China: A case study of Changting. *Transportation Research Part D: Transport and Environment*, 59: 361-374.
Huie, S. A. B. (2001). THE CONCEPT OF NEIGHBORHOOD IN HEALTH AND MORTALITY RESEARCH. *Sociological Spectrum*, 21 (3): 341-358.
Hägerstraand, T. (1970). WHAT ABOUT PEOPLE IN REGIONAL SCIENCE? *Papers in Regional Science*, 24 (1): 7-24.

Hägerstrand, T. (1970). *What about people in regional science?* Papers of the Regional Science Association: Springer. 6-21 pp.
Jenks, M. & Dempsey, N. (2007). Defining the neighbourhood: Challenges for empirical research. *Town Planning Review*, 78 (2): 153-177.
Jones, P. M., Dix, M. C., Clarke, M. I. & Heggie, I. G. (1983). *Understanding travel behaviour*.
Kitamura, R., Mokhtarian, P. L. & Laidet, L. (1997). A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation*, 24 (2): 125-158.
Krzyżanowski, M., Kuna-Dibbert, B. & Schneider, J. (2005). *Health effects of transport-related air pollution*: WHO Regional Office Europe.
Kwan, M.-P. & Weber, J. (2008). Scale and accessibility: Implications for the analysis of land use–travel interaction. *Applied Geography*, 28 (2): 110-123.
Kwan, M.-P. (2012a). How GIS can help address the uncertain geographic context problem in social science research. *Annals of GIS*, 18 (4): 245-255.
Kwan, M.-P. (2012b). The Uncertain Geographic Context Problem. *Annals of the Association of American Geographers*, 102 (5): 958-968.
Lacewing, M. (2017). *Philosophy for a Level: Metaphysics of God and Metaphysics of Mind*: Taylor & Francis.
Ladd, B. (2012). “You can't build your way out of congestion.” – Or can you? *disP - The Planning Review*, 48 (3): 16-23.
Levinson, D. M. & Kumar, A. (1997). Density and the Journey to Work. *Growth and Change*, 28 (2): 147-172.
Lewis-Beck, M. S. (1980). *Applied regression: An introduction. Series: Quantitative applications in the social sciences*: Newbury Park, CA: SAGE Publications.
Litman, T. (2017). *Generated traffic and induced travel*: Victoria Transport Policy Institute.
Lösch, A. (1954). *The economics of location*. New Haven: Yale University Press.
Ma, J. & Goulias, K. (1998). *Forecasting home departure time, daily time budget, activity duration and travel time using panel data*. Transportation Research Board Annual Meeting, Washington, DC.
Milakis, D., Cervero, R. & van Wee, B. (2015). Stay local or go regional? Urban form effects on vehicle use at different spatial scales: A theoretical concept and its application to the San Francisco Bay Area. *2015*, 8 (2).
Miller, H. J. (2016). Time Geography and Space–Time Prism. In *International Encyclopedia of Geography: People, the Earth, Environment and Technology*: John Wiley & Sons, Ltd.
Millward, H., Spinney, J. & Scott, D. (2013). Active-transport walking behavior: destinations, durations, distances. *Journal of Transport Geography*, 28: 101-110.
Mokhtarian, P. L. & Salomon, I. (2001). How derived is the demand for travel? Some conceptual and measurement considerations. *Transportation Research Part A*, 35 (8): 695-719.
Mokhtarian, P. L. & Chen, C. (2004). TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets. *Transportation Research Part A: Policy and Practice*, 38 (9-10): 643-675.
Mokhtarian, P. L., Salomon, I. & Singer, M. E. (2015). What moves us? An interdisciplinary exploration of reasons for traveling. *Transport reviews*, 35 (3): 250-274.
Newman, P. W. G. & Kenworthy, J. R. (1989). Gasoline Consumption and Cities. *Journal of the American Planning Association*, 55 (1): 24-37.
Nielsen, T. A. S., Olafsson, A. S., Carstensen, T. A. & Skov-Petersen, H. (2013). Environmental correlates of cycling: Evaluating urban form and location effects based on Danish micro-data. *Transportation Research Part D*, 22: 40-44.

Nielsen, T. A. S. & Skov-Petersen, H. (2018). Bikeability – Urban structures supporting cycling. Effects of local, urban and regional scale urban form factors on cycling from home and workplace locations in Denmark. *Journal of Transport Geography*, 69: 36-44.
Niemeier, D., Bai, S. & Handy, S. L. (2011). The impact of residential growth patterns on vehicle travel and pollutant emissions. *Journal of Transport and Land Use*, 4 (3): 80.
Noland, R. B. & Lem, L. L. (2002). A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research Part D: Transport and Environment*, 7 (1): 1-26.
Norway's Governmet. (2014). Central government policy guidelines for coordinated land use and transport planning in 1993, amended in 2014. *2014:1*: Ministry of Local Government and Modernisation.
Næss, P., Røe, P. G. & Larsen, S. L. (1995). Travelling Distances, Modal Split and Transportation Energy in Thirty Residential Areas in Oslo. *Journal of Environmental Planning and Management*, 38 (3): 349-370.
Næss, P. & Sandberg, S. (1996). Workplace location, modal split and energy use for commuting trips. *Urban Studies*, 33 (3): 557.
Næss, P. & Sandberg, S. L. (1996). Workplace Location, Modal Split and Energy Use for Commuting Trips. *Urban Studies*, 33 (3): 557-580.
Næss, P., Sandberg, S. v. L. & R∅e, P. G. (1996). Energy use for transportation in 22 Nordic towns. *Scandinavian Housing and Planning Research*, 13 (2): 79-97.
Næss, P. & Jensen, O. B. (2004). Urban structure matters, even in a small town. *Journal of Environmental Planning and Management*, 47 (1): 35-57.
Næss, P. (2005). Residential location affects travel behavior—but how and why? The case of Copenhagen metropolitan area. *Progress in Planning*, 63 (2): 167-257.
Næss, P. (2006). *Urban structure matters: residential location, car dependence and travel behaviour*. The RTPI library series, vol. 13. London: Routledge.
Næss, P. (2007a). The impacts of job and household decentralization on commuting distances and travel modes: Experiences from the Copenhagen region and other Nordic urban areas. *Informationen zur Raumentwicklung*, 2 (3): 149-168.
Næss, P. (2007b). Residential location and travel in Hangzhou metropolitan area. *NIBR Report*, 2007:1. Oslo, Norway: Norwegian Institute for Urban and Regional Research.
Næss, P. (2009). Residential Self-Selection and Appropriate Control Variables in Land Use: Travel Studies. *Transport Reviews*, 29 (3): 293-324.
Næss, P. (2011a). 'New urbanism'or metropolitan-level centralization? A comparison of the influences of metropolitan-level and neighborhood-level urban form characteristics on travel behavior. *Journal of Transport and Land Use*, 4 (1): 25-44.
Næss, P. (2011b). 'New urbanism' or metropolitan-level centralization? A comparison of the influences of metropolitan-level and neighborhood-level urban form characteristics on travel behavior. *Journal of Transport and Land Use*, 4 (1): 20.
Næss, P. (2013). Residential location, transport rationales and daily-life travel behaviour: The case of Hangzhou Metropolitan Area, China. *Progress in Planning*, 79 (0): 1-50.
Næss, P. (2014). Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies. *Journal of Transport and Land Use*, 7 (3): 23.
Næss, P., Andersen, J., Nicolaisen, M. S. & Strand, A. (2014). Transport modelling in the context of the 'predict and provide'paradigm. *European Journal of Transport and Infrastructure Research*, 14 (2): 102-121.
Næss, P. (2015). Built Environment, Causality and Travel. *Transport Reviews*, 35 (3): 275-291.

Næss, P. (2016). Urban Planning: Residential Location and Compensatory Behaviour in Three Scandinavian Cities. In Santarius, T., Walnum, H. J. & Aall, C. (eds) *Rethinking Climate and Energy Policies: New Perspectives on the Rebound Phenomenon*, pp. 181-207. Cham: Springer International Publishing.

Næss, P., Strand, A., Wolday, F. & Stefansdottir, H. (2017). Residential location, commuting and non-work travel in two urban areas of different size and with different center structures. *Progress in Planning*.

Næss, P. (2018). Validating explanatory qualitative research: Enhancing the interpretation of interviews in urban planning and transportation research. *Applied Mobilities*, Forthcoming.

Orski, C. K. (1985). Suburban mobility: the coming transportation crisis. *Transp. Q.;(United States)*, 39 (2).

Ory, D. T. & Mokhtarian, P. L. (2005). When is getting there half the fun? Modeling the liking for travel. *Transportation Research Part A*, 39 (2): 97-123.

Perry, C. A. (1929). City Planning for Neighborhood Life. *Social Forces*, 8 (1): 98-100.

Redmond, L. S. & Mokhtarian, P. L. (2001). The positive utility of the commute: modeling ideal commute time and relative desired commute amount. *Transportation*, 28 (2): 179-205.

Sallis, J. F., Frank, L. D., Saelens, B. E. & Kraft, M. K. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. *Transportation Research Part A: Policy and Practice*, 38 (4): 249-268.

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K. & Kerr, J. (2006). An ecological approach to creating active living communities. *Annu. Rev. Public Health*, 27: 297-322.

Salomon, I. & Mokhtarian, P. L. (1998). What happens when mobility-inclined market segments face accessibility-enhancing policies? *Transportation Research Part D: Transport and Environment*, 3 (3): 129-140.

Scheiner, J. (2010). Interrelations between travel mode choice and trip distance: trends in Germany 1976–2002. *Journal of Transport Geography*, 18 (1): 75-84.

Schutt, R. K. (2015). *Investigating the social world: the process and practice of research*. Los Angeles: SAGE. XXV, 661 s. : ill. pp.

Schwanen, T., Dieleman, F. M. & Dijst, M. (2001). Travel behaviour in Dutch monocentric and policentric urban systems. *Journal of Transport Geography*, 9 (3): 173-186.

Schwanen, T. & Dijst, M. (2002). Travel-time ratios for visits to the workplace: the relationship between commuting time and work duration. *Transportation Research Part A: Policy and Practice*, 36 (7): 573-592.

Schwanen, T. & Mokhtarian, P. L. (2004). The extent and determinants of dissonance between actual and preferred residential neighborhood type. *Environment and planning. B, planning and design*, 31: 759-8135.

Schwanen, T. & Mokhtarian, P. L. (2005). What if you live in the wrong neighborhood? The impact of residential neighborhood type dissonance on distance traveled. *Transportation Research Part D*, 10 (2): 127-151.

Shan, R., Zhong, M. & Lu, C. (2013). Comparison Between Traditional Four-Step & Activity-Based Travel Demand Modeling-A Case Study of Tampa, Florida. In *ICTIS 2013: Improving Multimodal Transportation Systems-Information, Safety, and Integration*, pp. 627-633.

Singleton, R. A. & Straits, B. C. (2010). *Approaches to social research*. New York: Oxford University Press. XVIII, 654 s. : ill. pp.

Skjeggedal, T., Northug, J., Wollan, G. & Ystad, D. (2003). Fortettingsrealisme. *Plan*, 6/2003: 56-63.

Statistics Norway. (2015). *Land use in urban settlements. Area and population of urban settlements, by densely populated area, contents and year*. Statistikkbanken, Table: 04859. Available at: http://www.ssb.no (accessed: January 29).

Statistics Norway. (2016). *Greenhouse gases, by energy product, pollutant, source (activity), contents and time.* Statistikkbanken, Table: 04859. Available at: https://www.ssb.no (accessed: January 30).

Steffansen, R. (2017). *The Norwegian Second Home Phenomenon. A critical perspective*. Ås, Norway: Norwegian University of Life Sciences, Department of Urban and Regional Planning.

Steg, L., Vlek, C. & Slotegraaf, G. (2001). Instrumental-reasoned and symbolic-affective motives for using a motor car. *Transportation Research Part F: Traffic Psychology and Behaviour*, 4 (3): 151-169.

Stevens, M. R. (2017). Does Compact Development Make People Drive Less? *Journal of the American Planning Association*, 83 (1): 7-18.

Sun, B., He, Z., Zhang, T. & Wang, R. (2016). Urban spatial structure and commute duration: An empirical study of China. *International Journal of Sustainable Transportation*, 10 (7): 638-644.

Sundt, P., Schulze, P.-E. & Syversen, F. (2014). Sources of microplastics-pollution to the marine environment, M-321/2015: the Norwegian Environment Agency. Report no. M-321/2015. 86 pp.

Van Wee, B. (2009). Self-Selection: A Key to a Better Understanding of Location Choices, Travel Behaviour and Transport Externalities? *Transport Reviews*, 29 (3): 279-292.

van Wee, B., Annema, J. A. & Banister, D. (2013). *The transport system and transport policy: an introduction*: Edward Elgar Publishing.

van Wee, B. & Handy, S. (2016). Key research themes on urban space, scale, and sustainable urban mobility. *International Journal of Sustainable Transportation*, 10 (1): 18-24.

Vilhelmson, B. (1999). Daily mobility and the use of time for different activities. The case of Sweden. *GeoJournal*, 48 (3): 177-185.

Wegener, M. (2004). Overview of land use transport models. In *Handbook of transport geography and spatial systems*, pp. 127-146: Emerald Group Publishing Limited.

Wolday, F. (2018a). Built environment and car driving distance in a small city context. *Journal of Transport and Land Use*, Forthcoming.

Wolday, F. (2018b). The effect of neighborhood and urban center structures on active travel in small cities. *(Under review)*.

Wolday, F., Cao, J. & Næss, P. (2018). Examining factors that keep residents with high transit preference away from transit-rich zones and associated behavior outcomes. *Journal of Transport Geography*, 66: 224-234.

Wooldridge, J. M. (2014). *Introduction to econometrics*. United Kingdom: Cengage Learning EMEA.

Zegras, C. (2010). The built environment and motor vehicle ownership and use: Evidence from Santiago de Chile. *Urban Studies*, 47 (8): 1793-1817.

Zhang, J. & Xie, Y. (2015). Optimal Intra-Urban Hierarchy of Activity Centers—A Minimized Household Travel Energy Consumption Approach. *Sustainability*, 7 (9): 11838.

Zhang, L., Hong, J. H., Nasri, A. & Shen, Q. (2012). How built environment affects travel behavior: A comparative analysis of the connections between land use and vehicle miles traveled in US cities. *Journal of Transport and Land Use*, 5 (3).

Zhou, B. & Kockelman, K. (2008). Self-selection in home choice: Use of treatment effects in evaluating relationship between built environment and travel behavior. *Transportation Research Record: Journal of the Transportation Research Board* (2077): 54-61.

Ås, D. (1978). Studies of time-use: problems and prospects. *Acta Sociologica*, 21 (4): 125-141.

7. Articles I-IV – full length

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Examining factors that keep residents with high transit preference away from transit-rich zones and associated behavior outcomes

Fitwi Wolday[a,*,1], Jason Cao[b,2], Petter Næss[c,3]

[a] Department of Urban and Regional Planning, Norwegian University of Life Sciences, Norway
[b] Humphrey School of Public Affairs, University of Minnesota, United States
[c] Department of Urban and Regional Planning, Norwegian University of Life Sciences, Norway

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ABSTRACT

Many studies on travel-induced residential self-selection assume that travel attitudes are strong enough to influence people's residential decisions. Using quantitative and qualitative methods, this article investigates the impacts of preference for transit and other residential preferences on residential location choice. Employing preference ranking, logistic regression and ANOVA tests on survey data from the Oslo metropolitan area, we find that individuals with simultaneously high preference for transit and low preference for attributes related to households with children are likely to reside in transit-friendly neighborhoods. Transit preference, while important in residential choice, is more so as second tier after other more important preferences related to life-cycle/demographics are satisfied. Individuals who prefer transit but live in transit-poor zones tend to have higher preference for private garden, a larger number of children, lower income, and are older. Variations in access to transit and transit preference have significant influences on transit use. The results of qualitative interviews are also consistent with these findings and substantiate the mechanism by which the built environment and travel preference affect residential and travel choices.

1. Introduction

Travel-induced residential self-selection (RSS) has become a subject of heated debates within land-use and transport research during the past two decades (van Wee and Handy, 2016). The widely held assumption is that people tend to select their residential neighborhoods based on their travel preference, in which case the preference would be a source of bias in the relationship between the built environment (BE) and travel behavior. As a result, travel preference has to be taken into account in order to purge this bias from the independent effect of BE on travel behavior. However, two issues need nuance about the idea of travel-induced residential self-selection. First, preference is an integral part of the demand for a good or service. For the most part, people travel, say, by transit because of their preference to do so. Hence, it is difficult to disband travel by transit from the preference to travel by transit. Consequently, controlling for transit preference may underestimate true BE effects on travel behavior (Chatman, 2009; Næss, 2014). Second, not all who prefer transit could realize their desired residential neighborhood. The ultimate location decision is an outcome of tradeoffs between various competing criteria. So, how strong is the influence of transit preference from a set of competing criteria in neighborhood choice?

Using data collected in the Oslo metropolitan area in 2015, this study aims to answer three interrelated research questions: (1) How important is transit preference in residential location choice? (2) Which factors cause transit-preferring people to live in areas with poor access to transit? (3) How do transit preference and transit access jointly factor into the difference in transit use? This study combines quantitative and qualitative analysis to gain a better insight into the relationship between transit preferences, neighborhood choice and the resulting travel behavior.

The Norwegian context provides an important supplement to the mainstream of studies on RSS that are conducted in countries where transit investment and use are less widespread than in Scandinavia. In Norway, the use of land-use policies to counter the negative effects of motorized travel has had relatively strong political backing and the compact city has had a strong status as a planning ideal since the mid-1980s. The Norwegian government adopted the *central government policy*

* Corresponding author.
E-mail addresses: hamdwold@nmbu.no (F. Wolday), cao@umn.edu (J. Cao), petter.nass@nmbu.no (P. Næss).
[1] https://www.nmbu.no/en/faculty/landsam.
[2] https://www.hhh.umn.edu/.
[3] https://www.nmbu.no/en/faculty/landsam.

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guidelines for coordinated land use and transport planning in 1993, which were amended in 2014 (Norway's Government, 2014). These guidelines state that land use and transport systems should "promote the development of compact cities and settlements, reduce the need for transport and facilitate forms of transport that are climate-friendly and environmentally friendly" (Norway's Government, 2014:1). Oslo has pursued a pronounced densification policy since the mid-1980s. As a result, the population density within the continuous urban area increased by as much as 37% over the period 1985–2016. The population density increase has been especially high in the central parts of Oslo (Statistics Norway, 2016; Municipality of Oslo, 2017). Oslo has a predominantly monocentric urban structure and is strongly invested in controlling sprawl. The city has an extensive transit service with wide spatial coverage. By the year 2035, Oslo's population is projected to increase by 25% compared to 2017 and the city has an ambitious plan to capture the resulting travel demand by transit and non-motorized means.

The paper is organized in six sections. The following section reviews the literature and situates our study in the context. Next, data and method are discussed, followed by the results section. Qualitative analysis is presented in section five with concluding remarks as the final section.

2. Literature review

Travel-induced residential self-selection refers to individuals' tendency to select their residential location based on their preferred travel patterns (Schwanen and Mokhtarian, 2004). When travel preferences significantly influence residential location choice, preferences would be correlated to both BE and travel behavior. The implication is that empirical research about BE-effects on travel behavior would be biased if travel-induced residential sorting were not considered (Schwanen and Mokhtarian, 2005; Cao et al., 2009; Van Wee, 2009).

The self-selection bias refers to over- or under-estimation of BE-effects on travel behavior when RSS is not accounted for. A standard practice for reducing self-selection bias has been to explicitly take those preferences into account in empirical analysis (Kitamura et al., 1997; Bagley and Mokhtarian, 2002; Shay and Khattak, 2005;Khattak and Rodriguez, 2005; Handy et al., 2006; Frank et al., 2007; Circella et al., 2008; Zhou and Kockelman, 2008; Næss, 2009; Cao et al., 2009; Targa and Clifton, 2005; Cao and Cao, 2014; Stevens, 2017). Other scholars, however, dispute that accounting for RSS would improve the accuracy of BE-estimates (Chatman, 2009, 2014; Næss, 2009, 2014). Næss (2009, 2014) for example presents empirical as well as theoretical grounds showing RSS does not significantly bias BE-effects. Instead, argues Author, RSS should be seen as a mechanism through which BE-influences are translated into travel behavior. Controlling for RSS, goes the argument, would exacerbate specification error rather than improve it and would likely lead to underestimation of the true BE-effects.

Irrespective of whether travel preferences co-determine travel behavior alongside BE or just facilitate BE-effects on travel behavior, the bottom line is that the preferences have a significant role in either diminishing or magnifying the BE-effects with important implications for urban policy. New alternative developments such as investment in public transport infrastructure and associated transit-oriented development (TOD) are costly long-term commitments. The success of such interventions depends, among others, on two conditions. First, do BE-characteristics have a definitive causal influence on travel behavior? And how large is the magnitude of the influence? Second, does the supply of residential stock such as new TODs enable those preferring transit to move in?

The first condition requires untangling travel-induced RSS from BE-effects. The wealth of empirical research resoundingly concurs that the BE has a significant and independent influence on travel behavior beyond RSS. In other words, regardless of people's set of preferences, the urban structural setting they live in will have a significant influence in their observed travel behavior. This is consistently shown by the difference in travel behavior between residents who have similar preference but live in urban and suburban neighborhoods (Schwanen and Mokhtarian, 2004; Næss, 2006; Cho and Rodríguez, 2014). Moreover, Cao et al. (2009) presented an overview of empirical findings of 38 studies about RSS. Almost all the reviewed studies reported that while RSS explains some of the variation in travel behavior, the BE has a distinct influence on travel behavior. Studies in Northern European cities found that the BE exerts a significant influence on travel behavior (Næss, 2006; Elldér, 2014). Although the independent BE-effect is undisputed, the magnitude of RSS influence varies among studies. Generally, the influence of RSS on modal choice appears to be stronger in the US than Europe (Bertaud and Richardson, 2004), likely due to stronger patronage for transit systems in European cities.

The second condition relates to whether the BE allows for residents preferring transit and/or non-motorized travel to reside in the neighborhoods with matching BE characteristics. This issue has a supply and demand side to it. The supply side relates to the availability of dwellings with preferred attributes in transit neighborhoods (Boarnet, 2011). The supply side does not necessarily imply shortage of building stock. Transit hubs can be attractive for reasons other than transit accessibility. For example, individuals who appreciate vibrant urban atmosphere but do not prefer transit may crowd out transit-favoring individuals from TOD-neighborhoods (Cao and Chatman, 2016). The demand side, on the other hand, relates to the constrained optimization of a multi-criteria residential choice process where a tradeoff among the selection criteria results in transit-favoring individuals living in mismatched neighborhoods. In Oslo, for example, housing prices in the central city are much higher than in meso-urban or suburban parts of the metropolitan area.

Travel preferences are important in determining the extent to which transit systems are utilized. This is illustrated by the difference between consonant and dissonant residents in the same neighborhood (Schwanen and Mokhtarian, 2004; Næss, 2006). Residential dissonance is defined as the mismatch or lack of congruence between BE characteristics of individuals' residential neighborhood and their preference towards such characteristics (Schwanen and Mokhtarian, 2004). Consonant households indeed tend to travel differently than dissonant ones (Schwanen and Mokhtarian, 2005; De Vos et al., 2012).

The discussion about preferences focuses largely on travel-related self-selection bias. Such an understanding implicitly assumes that individuals can freely self-select to the locations fitting their preferred travel pattern (Ettema and Nieuwenhuis, 2017). This assumption consequently masks people who potentially would like to self-select but could not do so for various reasons. This brings us to an important question: to what extent can people self-select? Residential location choice, similar to other transactions, is a constrained optimization in a compensatory decision process involving tradeoffs among multitude and at times conflicting decision criteria (Schwanen and Mokhtarian, 2004; Cao, 2008; De Vos et al., 2012). These decision criteria include, but are not limited to, housing characteristics, demographics such as family size and age, resource endowments, locational advantages such as proximity to various destinations and transportation facilities. Individuals vary in the priority of the decision criteria. Given their resource endowment, they choose residential location that generates a satisfactory fulfillment of their preferences.

The selection process requires prioritizing since not all locational preferences could be realized due to various constraints. Hence, the actual residential location may end up being different from the optimal or preferred location, creating a mismatch in certain preferred attributes while the most pressing criteria are satisfied. Accordingly, people preferring transit may end up living in either transit-rich neighborhoods or car-oriented neighborhoods depending on the relative importance of transit-related factors among their decision criteria. Ettema and Nieuwenhuis (2017) also found RSS and BE to be marginally confounding as strong travel preferences weakly translate into residential selection in the Netherlands.

Addressing travel-related dissonance requires an understanding of the relative importance of travel-related preferences in residential location choice. We focus in this paper on a narrower form of travel preferences, specifically transit preferences. The RSS discussion rests mainly on the assumption that travel preferences are strong and of relatively high priority capable of inducing people to self-select. Previous research (Filion et al., 1999; Cao, 2008) indicates that travel preferences are second tier in residential location choice. Cao (2015b), using survey data from the Twin Cities, found housing affordability and safety to be top priority. The level of patronage to transit and hence its importance in location choice is expected to vary between locations with different levels of transit access. Access to transit ranks third among various reasons for choosing to live in a TOD in San Francisco but its ranking is much lower in Los Angeles and San Diego (Lund, 2006). This is not surprising because San Francisco is more transit-friendly than the latter two cities. Moreover, access to highway consistently ranks lower than access to transit in the three cities, as it is widely available.

The preference structure of dissonant residents and the characteristics that constitute them into mismatched with respect to travel preferences is crucial both in framing new alternative developments and in maximizing the responsiveness to it (Cao and Chatman, 2016; Chatman, 2014). The heterogeneous response to the BE (Chatman, 2014; Cao, 2015a; Lindelöw et al., 2017) and travel behavior (Schwanen and Mokhtarian, 2005; De Vos et al., 2012) with respect to preferences suggest that the effectiveness of alternative development would largely depend on whether potential residents are matched or mismatched with respect to their transit preference. Travel preferences being second tier in residential choice means that many residents with high transit preference are likely to end up in neighborhoods with poor transit service. The main question here is, thus, what causes these people to be dissonant? Previous findings show income to be one of the main causes of residential dissonance as low-income households may not afford their preferred residential location (Cao, 2015b; Næss, 2006). Other demographic factors are also important sources of dissonance. As Schwanen and Mokhtarian (2004) found, single suburban dwellers and large households in the city are likely to be dissonant.

The debates on RSS generally and the extent of bias it impacts specifically are hotly pursued in North American studies with many empirical studies reporting RSS as a significant confounding factor. On the other hand, self-selection bias is downplayed and land use-travel connection is stronger in many European studies (Ettema and Nieuwenhuis, 2017; Gim, 2012; Lindelöw et al., 2017; Næss, 2014). Part of the incongruence in empirical findings may emanate from the disparities in urban physical structures and their transport systems. European cities can be characterized as compact with strong city centers and better patronage to transit service compared to their North American counterparts (Bertaud and Richardson, 2004).For example, population density within the continuous urban area of Oslo (including suburban municipalities) was 37 persons per hectare in 2016, which is considerably higher than the 2005 figures for US cities such as San Francisco, Denver and Washington, with 19, 15 and 13 persons per hectare, respectively (Kenworthy and Inbakaran, 2011). In 2014, residents of the continuous urban area of Oslo made one third of their trips on foot or by bike, one fifth by mass transit and 47% by car. Measured in person kilometers (excluding air travel), non-motorized modes accounted for 7%, transit for 21% and car for 72% (PROSAM, 2015).

This paper includes a qualitative analysis on the rationales behind individual's choices as a way of giving further credence to the statistical analysis. According to Singleton and Straits (2010), four criteria ought to be met for a valid causal inference between two phenomena: statistical association, non-spuriousness, time precedence and causal mechanisms. Depending on data availability and method of analysis, the first three criteria can be handled fairly well using statistical methods. Addressing causal mechanisms however is outside the realm of statistical methodology and requires a qualitative research design. Although statistical analyses can reveal patterns and relationships that might be a result of causal influences, they cannot themselves establish the existence of causality. The latter (establishing causality) requires a qualitative research – either in the actual study or in previous research on which the theories informing the study are based.

With notable exceptions (Næss, 2009, 2014; Chatman, 2014), many empirical studies were built under the assumption that travel attitudes drive RSS with little focus on whether and how the assumption holds. A sound theoretical foundation is an indispensable precedent of statistical analysis on causality. Without an elaborate understanding of the mechanisms of causal flows, model specification is likely to be inaccurate if not misleading (Næss, 2015). Methodological plurality is, hence, a clear advantage as qualitative methods can help fill the gaps left by quantitative techniques by clarifying the mechanism underlying behavioral changes (Clifton and Handy, 2003; Røe, 2000).

3. Methods

3.1. Data and variables

The data utilized in this study came from a self-administered nine-page survey collected in the Oslo metropolitan area in 2015. The study was tailored to examine built environment impacts on travel behavior of the general population as well as recent movers. We drew 15,000 individuals using a combination of purposive and stratified random sampling. To ensure a sufficient coverage of the recent movers, we identified about 3000 newly built dwellings based on information provided by building companies and realtors. After identifying individual addresses with the help of real estate developers and the online mapping and address service www.finn.no, 2500 individuals were selected randomly from these addresses. The remaining 12,500 units were randomly drawn from a geographically stratified sampling frame. Distance belts from the city center (as the crow flies) were used as stratification criteria, which led to five strata, 0–5 km; 5–10 km; 10–15 km; 15–20 km and 20–30 km. From each distance belt, 2500 individuals (one individual from each residential unit) were randomly selected. The numbers of respondents within varying distances from the city center are shown in Table 1.[4]

We sent an invitation letter with information about the survey and a guide on how to respond to each individual in the sample. The survey had a two-week deadline with no follow up or reminders afterwards. In total, we received 1992 acceptably completed questionnaires, yielding a response rate of 13.3%. Some respondents moved away from the case region and were subsequently excluded leaving us with a final sample size of 1904 respondents. This is acceptable for a survey of this length, since the response rate for surveys administered to the general population have declined substantially over the last 20–30 years (Amundsen and Lie, 2013). Response rates are now typically 10–20% (Hjorthol et al., 2014). Furthermore, the response rate is within the mainstream for studies on this topic.[5]

We recruited participants for the qualitative interviews among questionnaire respondents who had stated their willingness to be interviewed. When selecting interviewees, we were keen to include individuals from different residential locations (central city, close to second-order centers and non-central location) and varying population groups in terms of household composition, employment and education. Altogether, 17 interviews were carried out, six from the central city, three from locations close to second-order centers, and eight from non-central location of the metropolitan region. The interviews, each lasting

[4] The respondents are fairly equally distributed among the strata of distance belts. Although the central areas (within 15 km from the city center) get a little higher representation in terms of number of respondents, this is justifiable as higher residential densities characterize the central areas.

[5] As an example, the response rate is similar to a much-cited American study (Kitamura et al., 1997) which had a net response rate of 11%.

Table 1
Distribution of survey respondents and interviewees at different distance belts from the city center.

Residential distance from the city center	Number of respondents in each distance belt	
	Survey respondents	Interviewees
0–5 km	414	6
5–10 km	326	2
10–15 km	360	5
15–20 km	251	2
20–30 km	317	1
Over 30 km	200	1
Missing	36	
Total	**1904**	**17**

Note: The outermost strata (strata 5) in the sampling stage had a maximum distance of 30 km from the city center. The last group in Table 1, however, extends farther than 30 km from the city center. The discrepancy is primarily a result of how distance was measured during stratification and after the data were collected. During stratification, the distance from the city center to the concentric distance belts was measured as the crow flies. For the final sample, the distance was measured along the road network.

for 1–1.5 h, were audio-recorded and transcribed. The topics addressed in the interviews were chosen based on theoretical considerations and experience from our previous projects on residential location and travel (Næss, 2005, 2013).

Table 2 illustrates the characteristics of the sample. On average, gender distribution among the respondents is similar to that of the population mean. Respondents and interviewees tend to live in a larger household than the population. The respondents and interviewees also have higher education than is typical for the county populations. Together, these circumstances contribute to household income levels considerably higher among the respondents and interviewees than among the inhabitants of the two counties that encompass the Oslo metropolitan area. Moreover, there is a higher proportion of pensioners among the respondents and interviewees than in the general population, reflected in higher age and lower proportion of workforce participants in our samples. However, since this study does not aim to describe univariate distributions of certain variables but to examine the conditional relationships among them, the overrepresentation of certain groups of people in the sample is not expected to substantially affect the results (Babbie, 2007; Crano et al., 2015).

Besides socio-demographic and travel related variables, the survey also collected residential preference indicators. Respondents were asked to indicate the importance of 19 items relating to housing and neighborhood characteristics when they were looking for a place to live (or if they were to move to a new dwelling). Each item was measured on a four-point scale from “not at all important” (1) to “highly important” (4). Among the 19 indicators, two are related to transit: proximity to train/metro and proximity to bus/streetcar. They are the travel preference variables of interest in this study. Table 1A in the Appendix illustrates the measurements of residential preferences and socio-demographic attributes and their descriptive statistics.

Table 3
Definition of consonant and dissonant residents.

Transit preference	Access to transit		
	Rich	Mediocre	Poor
High	Transit rich consonant		Transit poor dissonant
Medium			
Low	Transit rich dissonant		Transit poor consonant

3.2. *Defining consonant and dissonant residents*

To answer the three questions presented in the introduction section, we need to define consonant and dissonant residents. Schwanen and Mokhtarian (2004), the seminal work on the dissonance between actual and preferred residential neighborhood, proposed five measures of dissonance. The first measure is based on a 2 × 2 classification on neighborhood type and residential preference (the pro-high density factor). A resident is dissonant if she prefers high (or low)-density development but lives in a suburban (or urban) neighborhood and she is consonant if her preference is congruent with her choice. To overcome the crudeness of dichotomous indicators, the second index uses continuous variables to measure gradual change in the level of residential dissonance. The third and fourth measures are constructed by interacting the first and second indices with an indicator of neighborhood attachment. The fifth measure is also a 2 × 2 classification based on neighborhood type and the residential preference factor. But it is more conservative than the first measure as they used the more extreme values to define dissonance (using one standard deviation away from its mean as the threshold, instead of the mean used in the first measure). Thereafter, several scholars proposed several other measures (confer (Cao, 2015a) for a summary). Although a 2 × 2 classification was used more often than other measures, there is no consensus on how to define consonant and dissonant residents in the literature.

This study proposes an alternative definition of consonant and dissonant residents based on transit supply and transit preference. In particular, residential areas are categorized as three zones based on the level of transit access. Using the transit map for Oslo, we found that residential locations within 7 km from the city center of Oslo are highly accessible by either one or more high-frequency transit modes at a distance of less than half a kilometer from residences and hence are termed as transit-rich zones. Outside the 7-km buffer from the city center of Oslo, residents within a kilometer of a second-order center and those residing within half a kilometer of a local center have high transit access and therefore are also defined as living in transit-rich zones. Conversely, transit-poor zones consist of residential areas that simultaneously are farther than 15 km from the city center, at least 2.5 km away from a second order center and farther than 1 km from a local center. Other areas are regarded as zones with mediocre access to transit.

Table 2
Comparison of socioeconomic and demographic characteristics of survey respondents and interviewees with their population.

	Survey respondents (N = 1992)	Interviewees (N = 17)	Inhabitants in Oslo and Akershus counties
Average number of persons per household	2.29	2.76	1.94
Average number of children aged 0–6 years per household	0.23	0.70	0.15
Average number of children aged 7–17 years per household	0.35	0.35	0.13
Average age of respondents/interviewees (all aged 16 or more)	49.3	46.4	45.5
Gender (proportion female)	50.6%	58.8%	50.3%
Proportion of workforce participants among respondents/interviewees	68%	70.6%	81%
Average annual household income (1000 NOK)	1018	1013	812
Proportion with education at master level or higher	40%	41.2%	16%

Note: The counties of Oslo and Akershus include the Oslo metro area.

Table 4
Summary statistics of monthly transit trips by trip purpose.

Resident type	Commuting trips by transit			Non-work trips by transit			Commuting trips by train		
	Mean	Std. dev.	N	Mean	Std. dev.	N	Mean	Std. dev.	N
TRC	9.76	8.08	187	9.64	12.28	245	5.31	7.82	124
TRD	4.79	6.71	107	4.51	4.94	126	1.08	2.90	13
TPD	7.10	8.39	99	6.33	12.77	142	2.54	5.91	352
TPC	2.49	5.82	207	1.78	4.22	237	0.76	3.21	173

A composite transit preference indicator (score) was computed by combining the two transit preference items (proximity to train/metro and proximity to bus/streetcar), using a factor analysis in Stata. The resulting transit preference score is then grouped into three equal categories with the first category representing low transit preference while the third category representing high transit preference.

Using the two indicators, we create a 3 × 3 cross-tabulation and define consonant and dissonant residents as shown in Table 3. In a 2 × 2 classification, it is ambiguous to classify a resident with either of the two indicators close to its mean value. For example, if the transit preference score of a resident is slightly higher than the mean score, she is not substantially different from one of her neighbors whose transit preference score is slightly lower than the mean score. However, by definition, the two residents would be grouped into different categories: one is consonant and the other is dissonant. The 3 × 3 classification effectively addresses the issue.

As shown in Table 3, we identified four types of residents based on their preference outlook and the transit access provided by their residential zone. Among the residents with high transit preference, those residing in transit-rich zones are defined as transit-rich consonants (TRC) whereas those living in transit-poor zones are defined transit-poor dissonants (TPD). Similarly, for the residents with low transit preferences, those residing in transit-rich zones are defined as transit-rich dissonants (TRD) while those in transit-poor zones are defined as transit-poor consonants (TPC).

Table 4 presents a summary statistics of transit behavior for the four-abovementioned categories of residents. Transit behavior is measured as monthly[6] transit trips denominated by trip purpose. Commuting tips by transit refer to monthly commuting trips by bus, tram or metro. Commuting trips by train are reported separately. Non-work trips by transit are the sum total of transit trips by all four transit modes (tram, bus, metro and train) to seven non-work destinations (grocery stores, personal service such as bank and barber shops, entertainment and cultural facility, civic facility, restaurants and cafés, fitness facility as well as accompanying someone e.g. a child).

4. Quantitative results

4.1. How important is transit preference in the choice of transit zones?

Several previous studies have documented the existence of heterogeneous response to transit access depending on individual preferences (De Vos et al., 2012; Cao, 2015a; Kamruzzaman et al., 2016). First, we examine the preference outlook of residents in transit-rich zones (TRZ) and transit-poor zones (TPZ) to understand how important transit preference is in the choice of transit-rich zones. Table 5 illustrates the ranking of mean preference scores of transit-rich zones and transit-poor zones.

[6] Respondents were asked to report the number of transit trips to a given destination by selecting one of six pre-defined alternatives (Not at all, Less than 1 day a month, 1–3 days a month, One day a week, 2–3 days a week and ≥ 4 days a week). The results are then harmonized into number of trips per month.

Individuals in transit-rich zones highly value proximity to transit facility and proximity to shops, whereas, for residents in transit-poor zones, non-transport related attributes rank in the top three, with preference for bus/streetcar at the fourth place. On the other hand, although the ranking of the top three preferences are different between the two zone types, six out of the seven highly preferred characteristics are common to both types of zones. This highlights the importance of these characteristics in residential location choice.

To identify characteristics that may stand out in the preference scale, we calculated, following (Cao, 2015b), the proportion of individuals who rated the characteristics as highly important. For transit-rich zone residents, proximity to bus/streetcar and proximity to train/metro stand out as highly important with 46% and 43% of the residents respectively while private garden and good school/kindergarten are least preferred with 62 and 63% of transit-rich zone residents rating them as not at all important respectively. For residents in transit-poor zones, proximity to green areas stand out with 44% ranking it as "highly important".

One objective of the preference ranking is to see if there is a distinct pattern in the preferences between residents in transit-rich zones and transit-poor zones. According to the last column in Table 5, the two types of zones differ significantly in thirteen preferences but the difference in terms of preference for private garden is more prominent. Preference for good school/kindergarten and proximity to transit also differ sizably. Overall, individuals with high transit preference seem to self-select into transit-rich zones while the residential choice of those in transit-poor zones appear to be motivated by residential characteristics related to demographics and life-style.

So far, we have looked at preference categorizations without regard for whether the residents' transit preferences match or mismatch their zone characteristics. As such, it is less informative in understanding what distinguishes transit-rich consonant from transit-poor dissonant residents. Table 6 presents ranking of residential preference for different areas depending on whether respondents' residential area characteristics match or mismatch with their transit preference.

One research question of this paper is what factors keep people with strong transit preference away from living in transit-rich zones. Residents with high transit preference but residing in transit-poor zones are termed as transit-poor dissonant (TPD). Those whose high transit preferences matched with their residential characteristics are called transit-rich consonant (TRC). As shown in Table 6, TPD-residents' preference for private garden differs from that of TRC-residents by a large margin. TPD-residents also have significantly higher preferences for good school/kindergarten and scenic value (nice view).

To evaluate the relative importance of residential preference variables, a logistic regression on the likelihood of choosing transit-rich zones is modeled. The logit model captures the partial effect of a given transit preference after controlling for other residential preferences, demographics and socio-economic attributes. The dependent variable is coded as '1' for residents in transit-rich zones and '0' for residents in transit-poor zones. The independent variables in the model comprise of the 19 residential preference variables, education level (measured in five ordinal categories), gross annual personal income (measured in nine ordinal categories), availability of a driver's license (a dummy

Table 5
Residential preferences of residents living in transit-rich zones and transit-poor zones.

Residential preferences	Preference scores for transit-rich zone (TRZ) residents. obs. 625		Preference scores for transit-poor zone (TPZ) residents. obs. 558		Difference in preference scores between TRZ and TPZ (rank)
	Mean (rank)	Std. dev.	Mean (rank)	Std. dev.	
Proximity to bus/streetcar	**3.253 (1)**	0.844	**2.875 (4)**	1.011	**0.378 (4)****
Proximity to train/metro	**3.074 (2)**	1.007	2.616 (9)	1.084	**0.457 (3)****
Proximity to shops	**3.045 (3)**	0.867	2.817 (6)	0.922	0.228 (9)**
Proximity to green areas	**2.974 (4)**	0.875	**3.181 (1)**	0.894	− 0.207 (10)**
No social problems	2.738 (5)	1.023	**2.977 (2)**	0.978	− 0.239 (7)**
Opportunities for physical exercise	2.704 (6)	1.010	**2.891 (3)**	0.913	− 0.187 (11)**
Low housing costs	2.643 (7)	0.950	2.728 (7)	0.935	− 0.084 (14)
Good property management	2.586 (8)	1.016	2.572 (12)	0.992	0.014 (19)
Nice view	2.557 (9)	0.944	2.853 (5)	0.920	− 0.296 (5)**
Proximity to workplace	2.523 (10)	1.070	2.392 (14)	1.005	0.131 (13)*
Favorable investment object	2.491 (11)	1.035	2.529 (13)	1.011	− 0.037 (18)
Proximity to relatives and friends	2.446 (12)	0.999	2.595 (11)	0.978	− 0.149 (12)**
Undisturbed location	2.379 (13)	0.910	2.655 (8)	0.905	− 0.276 (6)**
Familiar neighborhood	2.302 (14)	0.990	2.223 (17)	0.993	0.080 (15)
Architecture	2.200 (15)	0.962	2.125 (19)	0.956	0.075 (17)
Distance to major road/rail line	2.054 (17)	1.035	2.292 (15)	0.988	− 0.238 (8)**
Easy access to shopping mall	2.054 (16)	0.954	2.131 (18)	0.954	− 0.076 (16)
Good school/kindergarten	1.795 (18)	1.134	2.253 (16)	1.245	**− 0.457 (2)****
Private garden	1.663 (19)	0.969	2.606 (10)	1.154	**− 0.942 (1)****

Note: Residential preference was measured on a four point scale ranging from 1 = 'not at all important' to 4 = 'extremely important'.
Figures in bold show the four highest ranking residential preferences.
* One-way ANOVA, preference scores significantly different at 0.05 significance level.
** One-way ANOVA, TRZ and TPZ preference scores significantly different at 0.01 significance level.

variable), respondents' age, household size, and number of children. Consistent with the mainstream of the literature, we treat ordinal scales as interval scales in the multivariate models. So all independent variables but driver's license enter the logit model as continuous variables. The variables insignificant at the 0.05 level were dropped to obtain a parsimonious model. Table 7 depicts significant variables in the final model.

Preferences related to transit proximity and those that are of distance minimizing nature (proximity to workplace and proximity to shops) increase the likelihood of residing in transit-rich zones. Individuals with high transit preferences do tend to self-select to transit-rich zones. Transit-rich zones also attract residents that have high preference for attributes not related to transport. Higher preferences for architecture and familiar neighborhood increase the probability of residing in transit-rich zones. Among the preference indicators with positive effects, proximity to shops has the highest (in terms of elasticity) influence on the probability of choosing transit-rich zones. Transit preference (preference for train/metro) and preference for familiar neighborhood also have considerable influence on the likelihood residential choice in transit-rich zones. The effects of the latter three

Table 6
Residential preferences of dissonant and consonant residents by residential area type.

Residential preference	TRC (N 254)	TRD (N 134)	TPD (N 149)	TPC (N 250)	Difference in preferences			
	Mean (rank)	Mean (rank)	Mean (rank)	Mean (rank)	TRC-TRD	TRC-TPD	TRD-TPD	TPD-TPC
Private garden	1.602 (17)	1.806 (15)	2.584 (11)	2.704 (5)	− 0.204 (11)*	**− 0.982 (1)****	**− 0.898 (1)****	− 0.120 (12)
Good school/kindergarten	1.787 (16)	1.761 (16)	2.322 (16)	2.264 (13)	0.026 (17)	**− 0.535 (2)****	**− 0.503 (2)****	0.058 (14)
Nice view	2.602 (9)	**2.530 (4)**	2.946 (5)	**2.796 (4)**	0.073 (16)	**− 0.344 (3)****	− 0.266 (9)*	0.150 (11)
Distance to major road/rail line	2.169 (15)	1.873 (14)	2.456 (14)	2.18 (14)	0.296 (8)**	**− 0.287 (4)****	− 0.307 (7)**	0.276 (8)**
Proximity to relatives and friends	2.614 (8)	2.239 (11)	2.879 (7)	2.412 (11)	0.375 (7)**	− 0.265 (5)*	− 0.174 (10)**	**0.467 (4)****
Undisturbed location	2.437 (11)	2.358 (7)	2.685 (9)	2.683 (6)	0.079 (15)	− 0.248 (6)*	− 0.325 (6)**	0.002 (17)
No social problems	2.831 (5)	**2.590 (2)**	**3.067 (3)**	**2.892 (2)**	0.241 (10)*	− 0.236 (7)*	− 0.302 (8)**	0.175 (10)
Low housing costs	**2.909 (3)**	2.388 (5)	**3.067 (4)**	2.516 (7)	**0.521 (3)****	− 0.158 (8)	− 0.128 (13)	**0.551 (3)****
Proximity to green areas	**3.055 (2)**	**2.761 (1)**	**3.195 (2)**	**3.156 (1)**	0.294 (9)**	− 0.140 (9)	**− 0.395 (4)****	0.039 (16)
Easy access to shopping mall	2.425 (12)	1.560 (17)	2.523 (13)	1.904 (17)	**0.865 (1)****	− 0.098 (10)	− 0.344 (5)**	**0.620 (2)****
Proximity to workplace	2.689 (7)	2.291 (10)	2.611 (10)	2.296 (12)	0.398 (6)**	0.078 (11)	− 0.005 (17)	0.315 (5)**
Proximity to shops	**3.394 (1)**	**2.575 (3)**	**3.336 (1)**	2.476 (9)	**0.819 (2)****	0.058 (12)	0.099 (15)	**0.860 (1)****
Architecture	2.362 (13)	2.172 (13)	2.309 (17)	2.004 (16)	0.191 (12)	0.054 (13)	0.168 (11)	0.305 (6)**
Favorable investment object	2.531 (10)	2.351 (8)	2.577 (12)	2.496 (8)	0.181 (13)	− 0.046 (14)	− 0.145 (12)	0.081 (13)
Opportunities for physical exercise	**2.890 (4)**	2.381 (6)	2.926 (6)	**2.876 (3)**	**0.509 (4)****	− 0.036 (15)	**− 0.495 (3)****	0.050 (15)
Good property management	2.760 (6)	2.336 (9)	2.738 (8)	2.46 (10)	0.424 (5)**	0.022 (16)	− 0.124 (14)	0.278 (7)**
Familiar neighborhood	2.354 (14)	2.194 (12)	2.369 (15)	2.164 (15)	0.160 (14)	− 0.015 (17)	0.030 (16)	0.205 (9)

Note: TRC – Transit-rich consonant: Residents with high transit preference and residing in transit-rich zones.
TRD – Transit-rich dissonant: Transit-rich zone residents with low transit preference.
TPD – Transit-poor dissonant: Residents with high preference for transit but residing in transit-poor zones.
TPC – Transit-poor consonant: Residents with low preference for transit and residing in transit-poor zones.
Figures in bold show the four highest ranking residential preferences.
* ANOVA with Bonferroni post hoc test, preference scores significantly different at 0.05 significance level.
** ANOVA with Bonferroni post hoc test, preference scores significantly different at 0.01 significance level.

Table 7
Binary logit model of residential choice in transit-rich zones.

	Coefficients	Robust std. dev.	P-value	Elasticity
Nice view	− 0.2936	0.0879	0.001	− 0.3974
Proximity to relatives and friends	− 0.1736	0.0830	0.036	− 0.2119
Proximity to workplace	0.2087	0.0855	0.015	0.2340
Proximity to train/metro	0.2956	0.0889	0.001	0.3642
Proximity to bus/streetcar	0.2410	0.1029	0.019	0.3247
Private garden	− 0.7557	0.0777	0.000	− 0.9319
Architecture	0.2759	0.0865	0.001	0.2771
Familiar neighborhood	0.3444	0.0857	0.000	0.3603
Proximity to shops	0.2794	0.1131	0.013	0.3696
Easy access to shopping mall	− 0.2596	0.0951	0.006	− 0.2584
Distance to major road/rail line	− 0.1769	0.0839	0.035	− 0.1921
Opportunities for physical exercise	− 0.2291	0.0864	0.008	− 0.3134
Respondent's age	− 0.0208	0.0056	0.000	− 0.4851
Household size	− 0.3344	0.0689	0.000	− 0.4102
Education	0.4562	0.0645	0.000	0.7609
Driver's license	− 0.9078	0.2811	0.001	− 0.3888
Constant	1.0792	0.5634	0.055	
Number of observations	1081			
Nagelkerke R^2	0.426			

variables are equivalent in size. Therefore, preferences for transit have considerable influences on the choice of transit-rich zones.

Among the preferences with negative effects, preference for private garden commands the strongest influence in the model for residential choice in transit-rich zones. Individuals with simultaneously high preferences for private garden and transit are likely to reside in areas that are mismatched with respect to their transit preference. Other preferences that are closely associated with low-density developments such as nice view, distance to major roads/rail line and easy access to shopping mall reduce the likelihood of residing in transit-rich zones. Preferences for physical exercise opportunities and proximity to family and friends also reduce the probability of choosing transit-rich zones.

Socio-demographic factors such as age and household size have significant and negative associations with residing in transit-rich zones. Possession of a driver's license also reduces the likelihood of residing in transit-rich zones. On the other hand, people with higher education have a higher likelihood of residing in transit-rich zones.

4.2. Why do transit-favoring residents live in transit-poor zones?

To understand factors that cause people with strong preferences for transit to reside in mismatched neighborhoods, we developed a binary logistic regression of residential location choice of residents who prefer transit on demographics, socio-economic attributes and 17 residential preference variables (not including preferences for train/metro and bus/streetcar). The demographic and socio-economic attributes include gross annual personal income, respondents' age, household size, children aged 7–17 in the household and possession of a driver's license. The dependent variable assumes the value ‘1’ if a resident with high transit preference lives in transit-poor zones and ‘0’ otherwise. Variables that are significant at the 0.05 level are retained in the final model (Table 8).

The results show that a few socio-demographics and preference for private garden have significant influences on the probability of transit-favoring individuals residing in transit-poor zones. Low-income and older people are more likely to be mismatched. Presence of children in a household also increases the likelihood of residential mismatch. The significance of low income is consistent with Cao (2008). In terms of elasticity, preference for private garden is the strongest source of residential mismatch for individuals with high transit preference. Because preference for private garden is correlated with household size and is

Table 8
Residential choice of mismatched individuals with high transit preference.

	Coefficients	Robust std. dev.	P-value	Elasticity
Personal gross annual income	− 0.1473	0.0495	0.003	− 0.5946
Children aged 7–17 in the household	0.3488	0.1562	0.026	0.0754
Age	0.0151	0.0066	0.021	0.5809
Preference for private garden	0.5097	0.0911	0.000	0.7442
Constant	− 3.0289	0.4563	0.000	
Number of observations	537			
Nagelkerke R^2	0.138			

closely associated with family with children, life cycle attributes appear to be significant contributors of the residential mismatch. This is similar to findings by Schwanen and Mokhtarian (2004) that large households and families in the city are likely to be mismatched. Furthermore, low-income individuals appear to be bid out of transit-rich zones, which tend to be associated with higher housing prices.

4.3. How does transit use differ between consonant and dissonant residents?

In this section, we compare transit behavior of consonant and dissonant residents in areas with different levels of transit access using one way ANOVA with post hoc tests. The acronyms TRC, TRD, TPD and TPC refer to transit-rich consonant, transit-rich dissonant, transit-poor dissonant and transit-poor consonant as above.

Results of one-way ANOVA are presented in Table 9. TRC-TRD, for example, shows the difference between transit-rich consonant and transit-rich dissonant residents. A positive difference means that consonant residents travel more frequently than dissonant residents do.

Individuals with high transit preference and residing in transit-rich zones travel more often by transit to work and non-work activities compared to the dissonant counterparts in the same area type. They also make significantly more trips by transit compared to transit-poor dissonant and transit-poor consonant residents. These are consistent with many previous findings (Næss, 2009, Cao, 2015a). Transit-rich dissonants have higher frequencies of commuting and non-work trips by transit compared to transit-poor consonant. This can be interpreted as an effect on travel behavior mainly due to differences in BE-attributes. By contrast, transit-poor dissonants travel consistently more by transit (mainly bus) for work and non-work purposes than transit-poor consonants. The differences in poor-transit zones reflect the influence of transit preferences.

A separate variable for train proximity was also calculated. Since the distribution and reach of train service is different from that of bus, tram and metro services, we calculated areas accessible by train separately. Train-rich zones are defined as residential locations within 1 km pedestrian distance (distance measured on the shortest pedestrian route) from a train station. Residential locations that are more than 1 km away from a train station are defined as train-poor zones. Combining train proximity with preference for train, four consonance/dissonance types were derived: train-rich consonant and dissonant as well as train-poor consonant and dissonant.

Residents with high train preference but different train proximities (TRC-TPD) differ significantly in their commuting trips by train, which highlights the role of BE on travel behavior. Individuals residing in train-poor zones but differ in their preference for train also differ significantly in their commuting trips by train. Train-poor dissonant residents commute by train more frequently than train-poor consonants, which reflects the effect of train preference on train use. Therefore, the difference between TRC and TPC results from both the built environment and train preference.

Table 9
Comparison of travel behavior between dissonant and consonant residents in different transit zones.

Difference between types of residents	Commuting trips by transit		Non-work trips by transit		Commuting trips by train*	
	Difference	Difference (%)	Difference	Difference (%)	Difference	Difference (%)
TRC-TRD	4.97 (0.000)	104%	5.14 (0.000)	114%	#	–
TRC-TPD	2.66 (0.018)	37%	3.31 (0.006)	52%	2.77 (0.000)	109%
TPD-TRD	2.31 (0.130)	48%	1.82 (0.699)	40%	#	–
TRC-TPC	7.27 (0.000)	292%	7.87 (0.000)	443%	4.56 (0.000)	602%
TRD-TPC	2.30 (0.044)	92%	2.73 (0.055)	154%	#	–
TPD-TPC	4.46 (0.000)	185%	4.55 (0.000)	256%	1.78 (0.005)	235%

Note: Numbers in parentheses indicate p-value.
The column 'difference (%)' shows the magnitude, in percent, of the difference in travel behavior between a pair of resident types. It is computed as the difference in number of trips divided by the number of trips in the second resident type [e.g. for the first raw in the table, this is calculated as (TRC-TRD)/TRD).

Not enough observations (only 13) for TRD to warrant a meaningful comparison.

* For train commutes, the last two columns, the acronyms TRC, TRD, TPD and TPC refer to train-rich consonant, train-rich dissonant, train-poor consonant and train-poor dissonant.

5. Qualitative results

The qualitative interview materials shed light on the complex mechanisms of residential location choice. Most interviewees whose neighborhoods offer proximity to facilities and good opportunities for travel by transit appreciate these characteristics, but this does not necessarily imply that they chose their residential neighborhood to realize a particular travel preference.

The interviewees' choices of residential locations are based on the same main considerations as their choices of locations for out-of-home activities (Næss et al., 2017). In both cases, two main groups of rationales are traded off against each other: choosing the best facility and minimizing the friction of distance. As a rationale for residential location, minimizing the friction of distance speaks in favor of choosing a location from which daily destinations such as workplace, places of education, stores, cultural facilities, restaurants and outdoor recreation opportunities can be easily accessed. The 'best facility' rationale is about the quality of the dwelling and its immediate neighborhood, in terms of characteristics such as dwelling type, private garden, view, absence of noise, etc., but also its price. Together with choice of workplace location, the choice of residential location is the facility type where most interviewees place the strongest emphasis on the 'best facility' rationale, compared to the 'minimizing the friction of distance' rationale. In particular, this applies to families with children. Most interviewees thus accept to spend considerable time and money on traveling to their regular trip destinations in order to be able to live in a preferred dwelling and neighborhood type. The 'minimizing the friction of distance' rationale is still important, especially among interviewees with a lifestyle including a high number of out-of-home activities. The distance that the interviewees want to minimize is, however, not only the distance to workplaces, stores, cultural facilities etc. For some interviewees, proximity to areas for outdoor recreation (ID17833) or the dwelling of an ex-husband with shared custody of children (ID52271) is more important than having as short distance to the workplace, shopping opportunities, culture and entertainment facilities etc. The majority of interviewees still emphasize the latter kind of destinations when they talk about the accessibility conditions of their residential location.

Moreover, the distance minimizing criterion is for most interviewees an issue of proximity (with an emphasis on having access to facilities within walking distance) just as much as facilitating easy access by transit. For interviewees living in the central parts of Oslo, travel mode choice rationales of convenience and frustration-aversion promote the use of travel modes other than the private car, since driving speeds are usually lower and parking conditions more difficult in these areas. These rationales can thus induce central city dwellers to choose non-motorized modes for short trips and public transport for trips beyond acceptable walking or biking distance. However, our material shows only a few examples of interviewees who emphasize high transit accessibility as an important reason for choosing their residential location.

Oslo's ***central city area*** is the part of the metropolitan area where transport-motivated residential self-selection is the most prevalent. For four of the six interviewees living in these districts, transport-related attitudes, including a preference for travel by transit, was an important and in some cases dominant reason for choice of residence. For example, the interviewee ID10078 chose to move to a public transport node at the edge of Oslo's central city area mainly because it offers easy access to different parts of the city by transit, but also because she could reach many daily-life destinations on foot or by her moped. Her chosen place of residence thus facilitated a lifestyle without a car. Similarly, ID10749 and her husband chose their centrally located residence to have facilities close by and to have good access to transit. They could thereby postpone car ownership for as long as possible. Another example is ID50711, who recently moved to an apartment on a previous industrial site, 4 km north of the city center. High accessibility by transit, particularly to her workplace, was the family's main criterion when selecting the new residence. Proximity to the husband's workplace and to shopping opportunities were other important criteria. This reflects a wish to pursue a lifestyle based on transit and non-motorized modes for daily-life travel. On the other hand, this interviewee also said that they preferred living near the forest (which is only 1.5 km from their dwelling) rather than living in the innermost areas. Their previous dwelling was located somewhat closer to the city center than their present dwelling, near another public transport node. Their choice of new residence could thus be seen as reflecting a wish to continue a travel behavioral lifestyle they had already become accustomed to.

In other cases, being able to reach daily destination within walking distance seems more important than transit accessibility per se, although the locations with the highest accessibility on foot are often also those with the best transit provision. One such example is an elderly couple (ID50136), who had recently moved from a single-family house in an outer suburb to a new apartment building next to Oslo's main railroad station. For them, close proximity to most facilities for daily activities and reduced dependence on car travel were the main reasons for moving.

Two other central city interviewees chose their place of residence mainly for other reasons than transport concerns and thus do not exemplify transport-related residential self-selection. ID12137 moved from an inner suburb to a neighborhood closer to the city center some years ago. She prefers to walk or go by transit and had only a 200 m walk to her job from her previous dwelling. After moving to the central city neighborhood, her commuting distance has increased to 8 km and she sometimes commutes by car (although most of her commutes are on foot or by transit). Her reason for living in this area is not primarily destination accessibility, but its strong social environment and cohesion, her affection for the area, in which she grew up, and proximity to many of her old friends. Another central city resident, ID11404, was about to move to a single-family house in a suburb when we interviewed him. He said that although his preferred modes of travel were walking, biking and streetcar, their move would likely result in more car travel, which he depicted as an undesirable side effect. The family's main reason for moving was that they want a dwelling with a garden where children could play unattended. This interview also illustrates how the choice of residential neighborhood can be a compromise between the preferences of two spouses. While the interviewee would, if he were to decide alone, prefer to live in the central city, his wife would prefer to live in the outskirts of the metropolitan area where you could get a bigger house and a bigger garden at a lower price.

Neighborhoods ***close to second-order centers*** are generally self-contained in terms of various non-work facilities, but not for workplaces. All three interviewees living in such neighborhoods appreciate the good accessibility to local facilities near their dwelling. However, transport-related selection criteria were not at the forefront when they chose their places of residences. Instead, social or lifecycle changes and aesthetic attributes were prominent.

In the ***least central parts*** of the metropolitan area, residential self-selection as a manifestation of travel attitudes seems to be weak. For six out of the eight interviewees, the main residential selection criteria reflect socio-demographic or economic circumstances and lifestyle aspects other than travel, including preference for single-family house with a garden, a wish for living close to large natural areas for outdoor recreation, and the lower housing prices in the outer suburbs. For example, ID16030 and his family moved to their present dwelling primarily to have more space, since they had then just got twins, in addition to their by then two-year old daughter. They also wanted the new dwelling to be a single-family house, and with a bigger plot than they had before. Another suburban interviewee, ID51437, says that he dislikes driving, particularly at peak periods, but still he moved to a neighborhood where he would have to travel by car to and from his workplace some days every week to pick up his children at kindergarten/school. At their previous dwelling, he did not need to drive to reach his daily activities. Only one non-centrally residing interviewee appear to have self-selected her residence partially due to her preference to travel by transit. For ID52375, a young woman without a driver's license, it was important to find an affordable dwelling with acceptable transit accessibility, preferably within her familiar part of the metropolitan area.

Overall, there is little evidence for transport related residential self-selection among the interviewees outside the central urban districts. It appears to be present in the neighborhoods with high transit accessibility. In this sense, it seems to be a unidirectional phenomenon in that individuals self-select towards areas with high access to transit and not away from it. This can indicate that residents in the suburban areas might tolerate their transport options as a bundled good (with other attributes they may prefer) rather than have a specific travel preference towards it.

6. Conclusion

Using Oslo as a case, this study answers the three research questions raised in the introduction section. It is unique because it investigates more thoroughly than earlier studies the relative importance of travel-related residential preferences compared to other residential choice criteria, as well as the relative importance of the built environment and travel attitudes, respectively, to transit use. It is also innovative because it illuminates the role of travel-related attitudes for residential choice not only through statistical analyses but also through in-depth qualitative interviews. Furthermore, the Norwegian context provides an important supplement to the mainstream of studies on RSS from countries where transit is less prevalent than in Scandinavia.

Our analysis shows that preferences related to demographics appear to have a stronger influence on residential choice while transit preferences, while important in residential choice, are more so as second tier. Furthermore, the significant positive influences of non-transport related preferences in transit neighborhood choice contributes to higher likelihood of residential dissonance with respect to transit preference. Specifically preference for private garden is the strongest among the preferences reducing the probability of residing in transit-rich zones. Transit preference and distance minimizing preferences such as proximity to shops and proximity to workplace increase the likelihood of residing in transit-rich zones. Non-transport preferences such as familiar neighborhood and preference for architecture also contribute to a higher likelihood of residing in transit-rich zones, which indicates the attractiveness of transit-rich zones for other amenities besides transit.

What causes individuals with high transit preference to reside in transit-poor zones? We found that demographic/life-cycle attributes and related neighborhood preferences are the strongest sources of dissonance. Households with children aged 7–17, older people, and individuals with high preference for private garden have a higher likelihood of residing in neighborhoods mismatched with their high transit preference. In addition, low-income individuals are more likely to be mismatched.

Consistent with previous findings, comparison between consonant and dissonant residents with respect to transit proximity shows that both transit preference and access to transit influence transit use. Transit consonant residents have higher commuting and non-work trip frequencies by transit compared to transit dissonant counterparts. In transit-poor zones, transit-poor dissonants travel consistently more often by transit (mainly bus) for work and non-work purposes than transit-poor consonants.

Material from our qualitative interviews show that people tend to self-select into transit neighborhoods because of their transit preferences. Such residential self-selection particularly occurs in central city areas where transit infrastructure is widely available. Our findings from the qualitative analysis also corroborate the findings from quantitative results above. Although people tend to self-select, demographics play an important role in influencing who gets to self-select. Empty nesters and childless households are likely to be better positioned to self-select than families with children. In addition to tastes and preferences as to what constitutes appropriate environment to raise a child, other entry barriers may also play a role. Central city districts have higher land-values. As the value of land gets expensive, substitution of capital for land increases, which again creates pressure on open landscape. This creates barrier at least in two ways: one, households with needs for greater floor space are likely to be bid out due to high land value. Second, the urban structure of densely built up area with less accessible open landscape, crowds out families with children. Such a barrier appears to induce a mechanism by which households with children that have a greater land per capita requirement tend to live outside the central urban districts with high transit access while households with lower requirement of floor space and outdoor areas tend to reside in central-city areas. Although there is definitely pull factor (a positive attitude) towards proximity to facilities and access to public transport, the push factors relating to affordability and outdoor spaciousness outweigh when it comes to certain groups in the life cycle.

Since this study demonstrates clearly that built environment characteristics influence the usage of transit independently of travel attitudes, a main policy implication is to locate a high share of future residential development in transit-rich neighborhoods if the aim is to increase transit ridership. To enable a higher number of those with transit preferences to live in transit-friendly neighborhoods, it is also important to remove some of the barriers presently causing transit-favoring individuals to reside in areas not matching these preferences. Among the causes of residential choice of mismatched individuals with high transit preference identified in Table 8, provision of private gardens is usually incompatible with transit-oriented development, since the space requirement of private gardens counteracts the density required to obtain a high passenger base for transit. The number of children is also a variable beyond the influence of public policy. However, offering safe playgrounds can partly meet the needs for a private garden of a household with children. More importantly, providing more housing options for low- and medium-income households at transit-rich locations is a possibility worth considering. Although provision of affordable housing at such locations might need some sort of subsidies due to the normally high land values in these areas, the public expenses thus incurred should be judged against the potential savings in terms of less congestion, a reduced need for expensive road construction, and a generally lower level of social segregation.

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Appendix A

Table 1A
Summary statistics of residential preference and sociodemographic variables.

	Variable name	Observations	Mean	Std. dev.	Min	Max
1	Nice view	1183	2.697	0.944	1	4
2	Proximity to green areas	1183	3.072	0.889	1	4
3	Low housing costs	1183	2.683	0.943	1	4
4	Undisturbed location	1182	2.509	0.918	1	4
5	Proximity to relatives and friends	1183	2.516	0.991	1	4
6	Proximity to workplace	1183	2.462	1.041	1	4
7	Proximity to train/metro	1183	2.858	1.068	1	4
8	Proximity to bus/streetcar	1183	3.074	0.945	1	4
9	Private garden	1182	2.108	1.160	1	4
10	Architecture	1183	2.165	0.960	1	4
11	Familiar neighborhood	1182	2.265	0.992	1	4
12	Good school/kindergarten	1183	2.011	1.209	1	4
13	No social problems	1183	2.850	1.007	1	4
14	Favorable investment object	1183	2.509	1.023	1	4
15	Proximity to shops	1183	2.937	0.900	1	4
16	Easy access to shopping mall	1183	2.090	1.013	1	4
17	Distance to major road/rail line	1183	2.167	0.961	1	4
18	Opportunities for physical exercise	1183	2.792	0.970	1	4
19	Good property management	1183	2.579	1.004	1	4
20	Respondent's age	1096	47.911	16.893	16	88
21	Gross personal annual income	1012	5.481	2.270	1	9
22	Education level	1106	3.809	1.311	1	5
23	Household size	1099	2.275	1.297	1	7
24	Children aged 7–17	1107	0.354	0.727	0	4
25	Driver's license	1100	0.872	0.334	0	1

Note: With the exception of driver's license, which is a dummy variable, all variables in Table 1A enter the model as continuous variables.
Residential preferences: The first 19 variables in the list in Table 1A are residential preference variables and were measured on a four-point scale ranging from '1' = 'not at all important' to '4' = 'highly important'.
Respondent's age is self-reported and is measured in number of years.

Gross personal annual income is a self-reported categorical variable measured in nine categories:

1. Below 100,000 kr
2. 100,000–199,999 kr
3. 200,000–299,999 kr
4. 300,000–399,999 kr
5. 400,000–499,999 kr
6. 500,000–599,999 kr
7. 600,000–699,999 kr
8. 700,000–799,999 kr
9. 800,000 kr or more

Education level shows the highest completed level of education and it is measured in five categories:

1. Elementary school
2. High school or professional secondary school
3. Education as skilled worker or craftsman
4. University college education, bachelor
5. University education, masters or higher

Household size is a count variable and measured as the number of individuals in the household.
Children aged 7–17 is a count variable showing the number of children in the household between seven and seventeen years.
Driver's license is a dummy variable indicating whether the respondent possesses a driver's license or not.

References

Amundsen, B., Lie, E., 2013. Fewer willing to participate in surveys. In: Forskning Magazine: 2/2013. The Research Council of Norway.
Babbie, E.R., 2007. The Practice of Social Research. Belmont, CA, Thomson Wadsworth.
Bagley, M.N., Mokhtarian, P.L., 2002. The impact of residential neighborhood type on travel behavior: a structural equations modeling approach. Ann. Reg. Sci. 36, 279–297.
Bertaud, A., Richardson, H.W., 2004. Transit and density: Atlanta, the United States and Western Europe. In: Richardson, H.W., Chang-Hee, C. (Eds.), Urban Sprawl in Western Europe and the United Sates. Ashgate, Farnham.
Boarnet, M.G., 2011. A broader context for land use and travel behavior, and a research agenda. J. Am. Plan. Assoc. 77, 197–213.
Cao, X., 2008. Is alternative development undersupplied? Examination of residential preferences and choices of Northern California movers. Transp. Res. Rec. 2077, 97–105.
Cao, X., 2015a. Heterogeneous effects of neighborhood type on commute mode choice: an exploration of residential dissonance in the Twin Cities. J. Transp. Geogr. 48, 188–196.
Cao, X., 2015b. Residential preference and choice of movers in light rail neighborhoods in Minneapolis, Minnesota. Transp. Res. Rec. 2494, 1–10.
Cao, J., Cao, X., 2014. The impacts of LRT, neighbourhood characteristics, and self-selection on auto ownership: evidence from Minneapolis-St. Paul. Urban Stud. 51, 2068–2087.
Cao, X., Chatman, D., 2016. How will smart growth land-use policies affect travel? A theoretical discussion on the importance of residential sorting. Environ. Plan. B Plan. Des. 43, 58–73.
Cao, X., Mokhtarian, P.L., Handy, S.L., 2009. Examining the impacts of residential self--selection on travel behaviour: a focus on empirical findings. Transp. Rev. 29, 359–395.
Chatman, D.G., 2009. Residential choice, the built environment, and nonwork travel: evidence using new data and methods. Environ Plan A 41, 1072–1089.
Chatman, D.G., 2014. Estimating the effect of land use and transportation planning on travel patterns: three problems in controlling for residential self-selection. J. Transp. Land Use 7 (3).
Cho, G.-H., Rodríguez, D.A., 2014. The influence of residential dissonance on physical activity and walking: evidence from the Montgomery County, MD, and Twin Cities, MN, areas. J. Transp. Geogr. 41, 259–267.
Circella, Giovani, Mokhtarian, Patricia L., Handy, Susan L., 2008. Land use, attitudes, and travel behavior relationships: a cross-sectional structural equations model for Northern California. In: Transportation Research Board 87th Annual Meeting, no. 08-0706.
Clifton, K.J., Handy, S.L., 2003. Qualitative methods in travel behaviour research. In: Transport Survey Quality and Innovation. Emerald Group Publishing Limited.
Crano, W.D., Brewer, M.B., Lac, A., 2015. Principles and Methods of Social Research, 3rd ed. Taylor & Francis Group, New York, NY, US, Routledge.
De Vos, J., Derudder, B., Van Acker, V., Witlox, F., 2012. Reducing car use: changing attitudes or relocating? The influence of residential dissonance on travel behavior. J. Transp. Geogr. 22, 1–9.
Elldér, E., 2014. Residential location and daily travel distances: the influence of trip purpose. J. Transp. Geogr. 34, 121–130.
Ettema, D., Nieuwenhuis, R., 2017. Residential self-selection and travel behaviour: what are the effects of attitudes, reasons for location choice and the built environment? J. Transp. Geogr. 59, 146–155.
Filion, P., Bunting, T., Warriner, K., 1999. The entrenchment of urban dispersion: residential preferences and location patterns in the dispersed city. Urban Stud. 36, 1317–1347.
Frank, L.D., Saelens, B.E., Powell, K.E., Chapman, J.E., 2007. Stepping towards causation: do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? Soc. Sci. Med. 65, 1898–1914.
Gim, T.-H., 2012. A meta-analysis of the relationship between density and travel behavior. Plan. Policy Res. Pract. 39, 491–519.
Handy, S.L., Cao, X., Mokhtarian, P.L., 2006. Self-selection in the relationship between the built environment and walking—Empirical evidence from Northern California. J. Am. Plan. Assoc. 72, 55–74.
Hjorthol, R., Engebretsen, Ø., Uteng, T.P., 2014. The Norwegian Travel Survey 2013/14 – key results (in Norwegian language). Norwegian Center for Transport Research: TØI Report 1383/2014, Oslo.
Kamruzzaman, M., Baker, D., washington, S., Turrell, G., 2016. Determinants of residential dissonance: implications for transit-oriented development in Brisbane. Int. J. Sustain. Transp. 10, 960–974.
Kenworthy, J.R., Inbakaran, C., 2011. Differences in transport and land use in thirteen comparable Australian, American, Canadian and European cities between 1995/6 to 2005/6 and their implications for more sustainable transport. In: 34th Australasian Transport Research Forum (ATRF), 28–30 September 2011 Adelaide, Australia.
Khattak, A.J., Rodriguez, D., 2005. Travel behavior in neo-traditional neighborhood developments: a case study in USA. Transp. Res. A Policy Pract. 39, 481–500.
Kitamura, R., Mokhtarian, P.L., Laidet, L., 1997. A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. Transportation 24, 125–158.
Lindelöw, D., Svensson, Å., Brundell-Freij, K., Winslott Hiselius, L., 2017. Satisfaction or compensation? The interaction between walking preferences and neighbourhood design. Transp. Res. Part D: Transp. Environ. 50, 520–532.
Lund, H., 2006. Reasons for living in a transit-oriented development, and associated transit use. J. Am. Plan. Assoc. 72, 357–366.
Municipality Of Oslo, 2017. Folkemengden etter kjønn og alder (B) (2004–2017) [Online]. The Municipality of Oslo, Oslo. http://statistikkbanken.oslo.kommune.no (Accessed 2017).
Næss, P., 2005. Residential location affects travel behavior - but how and why? The case of Copenhagen Metropolitan Area. Planning in Progress 63, 167–257.
Næss, P., 2006. Urban Structure Matters: Residential Location, Car Dependence and Travel Behaviour. Routledge, London.
Næss, P., 2009. Residential self-selection and appropriate control variables in land use: travel studies. Transp. Rev. 29, 293–324.
Næss, P., 2013. Residential location, transport rationales and daily-life travel behavior: the case of Hangzhou Metropolitan Area, China. Prog. Plan. 79, 1–50.
Næss, P., 2014. Tempest in a teapot: the exaggerated problem of transport-related residential self-selection as a source of error in empirical studies. J. Transp. Land Use 7 (23), 57–79.
Næss, P., 2015. Built environment, causality and travel. Transp. Rev. 35, 275–291.
Næss, P., Sebastian, P., Stefandottir, H., 2017. Causality not just correlation. Residential location, travel rationales and travel behavior accross metropolitan contexts. (Under review).
Norway's Government, 2014. Central government policy guidelines for coordinated land use and transport planning in 1993, amended in 2014. 2014:1. Ministry of Local Government and Modernisation.
PROSAM, RUTER/PROSAM (Eds.), 2015. Reisevaner i Osloområdet. En analyse av den nasjonale reisevaneundersøkelsen 2013/14. PROSAM, Oslo.
Røe, P.G., 2000. Qualitative research on intra-urban travel: an alternative approach. J. Transp. Geogr. 8, 99–106.
Schwanen, T., Mokhtarian, P.L., 2004. The extent and determinants of dissonance between actual and preferred residential neighborhood type. Environ. Plan. B Plan. Des. 31, 759–8135.
Schwanen, T., Mokhtarian, P.L., 2005. What if you live in the wrong neighborhood? The impact of residential neighborhood type dissonance on distance traveled. Transp. Res. D 10, 127–151.
Shay, E., Khattak, A.J., 2005. Auto ownership and use in neotraditional and conventional neighborhoods. Transp. Res. Rec. 1902, 18–25.
Singleton, R.A., Straits, B.C., 2010. Approaches to Social Research. Oxford University Press, New York.
Statistics Norway, 2016. Areal og Befolkning i Tettsteder (T). [Online]. Statistikkbanken, Table: 04859.: Statistics Norway. Available: https://www.ssb.no/ (Accessed December 14 2016).
Stevens, M.R., 2017. Does compact development make people drive less? J. Am. Plan. Assoc. 83, 7–18.
Targa, F., Clifton, K., 2005. The built environment and trip generation for non-motorized travel. J. Transp. Stat. 8, 55–70.
van Wee, B., 2009. Self-selection: a key to a better understanding of location choices, travel behaviour and transport externalities? Transp. Rev. 29, 279–292.
van Wee, B., Handy, S., 2016. Key research themes on urban space, scale, and sustainable urban mobility. Int. J. Sustain. Transp. 10, 18–24.
Zhou, B., Kockelman, K., 2008. Self-selection in home choice: Use of treatment effects in evaluating relationship between built environment and travel behavior. Transp. Res. Rec. 2077, 54–61.

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Built environment and car driving distance in a small city context

Fitwi Wolday
Norwegian University of Life Sciences
hamdwold@nmbu.no

Abstract: This article focuses on the effect of built-environment factors on travel behavior in the context of small cities. Urban size and spatial context are central to travel behavior analysis because of the spatio-temporal nature of transportation. Different urban structural attributes exert travel behavioral influences at different spatial scales (local vs. regional) and urban sizes. Due to this inherent geographic dimension in travel studies, findings from larger urban areas may not be transferable to small cities. Despite this, however, small cities remain scantily represented in the literature. Using multivariate analysis on survey data from three small cities in Norway, this paper finds that the built-environment effects on travel behavior are highly influenced by regional characteristics and the city's center structure (poly-centered vs. single centered). Residential proximity to the city center leads to reduced car driving distance through its distance-minimizing effect to concentrations of facilities for local travel. At the regional scale, proximity to the city center influences car driving distance via the higher likelihood among centrally located commuters of choosing transit as their commute mode.

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1 Background

A sizable share of the Norwegian as well as the European[1] population live in small cities. The latest figures from Statistics Norway, the national statistics office, show that about 23 percent[2] of the Norwegian population reside in small cities (with inhabitants ranging between 5000 and 30,000). Understanding the dynamics of travel behavior at this geographic scale is important in setting realistic sustainability oriented transportation and environmental goals and consequently designing appropriate policies to achieve them.

Due to the inherent urban structural differences induced by differences in urban size (small vs large cities) and geographic scale of analysis (local vs regional contexts), findings from larger urban areas may not be transferable to small cities. Yet, with very few exceptions (Næss & Jensen, 2004) small cities have conspicuously been overlooked in travel studies. Much of what we know about the relationship between built environment and travel behavior comes from larger metropolitan areas.

Various studies (Bhat & Guo, 2007; Hong, Shen, & Zhang, 2014; Kwan, 2012; Kwan & Weber, 2008) show that the geographic scale of analysis plays an important role for the significance and validity of empirical assertions on causality between built environment and travel behavior. Hence, knowledge based on a skewed focus towards larger metropolitan areas may lack external validity and thus offer little practical guidance for small-city planners. This article will complement the existing literature by investigating whether, and in which way, the distribution of residential locations in small cities influences travel behavior. Besides urban form characteristics, the article assesses the effect of demographic and socio-economic characteristics on travel behavior.

Most travel, at least most of the non-ad-hoc, recurring travel, starts from home and ultimately ends at home. Once households decide where to reside, travel scheduling decisions such as where to travel, how often, which route to take and which mode of travel to adopt etc. are made with a constant point of reference in mind, which is their place of residence (Ellegård & Vilhelmson, 2004). Consequently, understanding how the spatial distribution of dwellings relates to people's travel behavior is an important concern for urban planners. Studies in many cities and urban areas show that residential distance from the city center and the spatial configuration around these residences offer a consistent and strong explanation of the variations in travel behavior above and beyond the issue of residential self-selection (Cao, Mokhtarian, & Handy, 2009; Cho & Rodríguez, 2014; Ettema & Nieuwenhuis, 2017; Næss, 2009; Næss, Strand, Wolday, & Stefansdottir, 2017; Zegras, 2010).

Longer travel distances, lower non-motorized and transit mode shares, as well as higher car use are all strongly associated with residential distance from city centers. These associations make up the core argument for compact urban development as a gateway for sustainable travel. Attesting to this, planning authorities employ land-use strategies as preferred policy tools in reducing car driving and the overall quantity of travel, promote health-enhancing travel habits as well as to curb urban encroachment on nature and agricultural land. Norwegian national planning guidelines, for example, have among their main goals to reduce land-use-induced transport demand and promote environmentally friendly modes of travel. The guidelines state that land development patterns and provision of transportation facilities should promote compact urban development and environmentally friendly means of conveyance. Central locations should be exhaustively utilized through densification before expansive land development could be considered (Norway's Government, 2014). This legal provision allows at the same time for local adaptability. Understanding travel behavioral responses in cities with differing sizes and regional contexts is therefore an important contribution in devising policies to achieve the intended outcomes.

[1]Eurostat news release, 51/2012, March 30, 2012

[2]Statistics Norway, population in urban settlements, 2015

The distribution of dwellings in the urban space and the regional urban structure within which it is embedded induces people to adopt certain ways of travel. This again depends on the economic and socio-demographic attributes of the traveler, access to alternative means of transport and individual preferences and attitudes. The availability of destinations, the breadth of alternative means of transport and diversity of facilities may in turn be conditional on the size and density of a given urban area (city). To draw meaningful conclusions from the complex web of interrelationships, understanding the appropriate variables to be measured, the geographic scale of analysis and its regional context is therefore vital (Crane & Guo, 2012). This article will utilize survey data from three small cities with comparable population sizes but varying urban structures and hierarchical position at a regional scale.

The article is organized under seven sub-themes. The next section outlines the research problem and the derived research questions. Section 3 looks into the theoretical framework in some detail, followed by data description in Section 4. Section 5 focuses on the analytical model. Results and discussion appear in Section 6, followed by concluding remarks at the end.

2 Problem statement and research questions

The tendency of built environment characteristics to be triggered as causal factors at varying spatial scales is an important dimension in the nexus between built environment and travel behavior (Bhat & Guo, 2007; Milakis, Cervero, & van Wee, 2015). This is partly because size and regional hierarchy of cities have significant behavioral implications on travel decisions. Variation in city size is expected to influence people's travel behavior by varying the size of the concentrations of activities of interest as well as the range of activities present. As such, the size of a given city partly determines how different facilities are related in terms of origins and destinations of travel and the modes people use to access them.

One important representation of how facilities are related from travel behavioral perspective is residential distance from the city center. As mentioned in the previous section, residential location is, presumably, the most frequently investigated facility in travel studies, because it is where daily life is planned, travel scheduled, family life organized and not least it is the origin and ultimate destination of most of daily travel activities. Likewise, the city center, by providing the highest concentration of facilities in the urban space, establishes itself, presumably, as a highly attractive destination. The distance of residences from the city center, by bringing together the two important aspects of travel activity (the origin and destination), becomes an important construct in understanding the effect of built environment on travel behavior.

Residential distance from the city center has been an important and consistently robust representation of the influence of built environment on travel behavior in metropolitan areas (Cao, Næss, & Wolday, 2017; Ewing & Cervero, 2010; Næss, 2006, 2011; Næss et al., 2017; Zegras, 2010; Zhou & Kockelman, 2008). In two meta-analyses comparing built environment elasticities, Reid Ewing and Cervero (2010) and Stevens (2017) found residential distance to downtown to be the variable with the strongest influence (in terms of effect size) on driving distance. Investigating whether the same also holds for smaller cities with varying urban hierarchies will be an important contribution to the transferability of findings across city sizes and hence broader understanding of the built environment-travel behavior relationship.

The primary question this paper tries to address is whether car driving distance vary significantly with variation in residential distance from the city center in a small-city context. This main question is addressed by three follow-up questions. Firstly, how does the relationship between car driving distance and residential distance from the city center manifest itself after accounting for differences in demographics, socio-economic attributes and residential preferences? Questions pertaining to the effect of socio-economic and demographic attributes on travel behavior while controlling for residential distance from the city center are also addressed here. Secondly, how does the relationship between car driving distance and neighborhood built environment factors look like after accounting for residential distance from the city center, and differences in socio-economic and demographic attributes? Thirdly, how important are neighborhood and city-scale built environment factors in influencing total driving distance in the context of regional influence?

3 Theoretical framework

This section explores characteristics that may influence travel behavior in the context of a small city and the theoretical underpinning for those claims. But first, a brief theoretical argument as to why size matters and hence the focus on small cities is in order.

As put forth in Christaller's central place theory (1966), the establishment of firms in a given location depends on the minimum threshold of potential customers, on the one hand, and the maximum range its customers are willing to travel to acquire the goods and services it provides, on the other. Put differently, population size and its geographic distribution is crucial for the constellation of a variety of facilities at a given location. High density implies a threshold (critical mass) being met within a narrower range, which again means a large concentration of facilities in a small area. Although the significance of density is undisputed, it is, however, not a sufficient condition for a wide-ranging diversity to take root, and that is where size comes in. Some occupations require a large customer base and hence a wide catchment area. In such cases, densification may not contribute much unless the size satisfies the minimum threshold required. Population density can therefore be seen as an enabler - an enabler that creates conditions for destinations of interest (such as shops and other facilities) to establish themselves.

In small cities, the diversity of facilities, and therefore the number of potential destinations, will be limited by the low population size of these cities. For small-city dwellers, the significance of the city center as a major trip generator will also likely depend (in part) on city size. As a result, small-city dwellers may, for a variety of facilities, depend on locations other than those in the city where they reside. In this case, the relevance of the center of a small city can be expected to be weakened somewhat. Whether neighboring, higher-order destinations can be viable alternative options will, however, depend on the position of the small city in question in a regional hierarchy of cities and its proximity to the nearest higher-order city.

An attempt to explain the causal nature of the relationship between urban form and travel behavior is a challenging task, given the diversity of reasons people may have for traveling. The multidimensional nature of urban form characteristics, the moderating effect of individual and household characteristics as well as spatial scale of analysis (Bhat & Guo, 2007; Boarnet & Crane, 2001a; Ewing et al., 2014) are other additional factors that add to the complexity. Fortunately, a lot of progress has been made in not only describing but also in explaining travel behavior (and the role of the built environment) over the last two decades. Boarnet and Crane (2001b), Handy, Cao, and Mokhtarian (2005), Næss (2006, 2013), Røe (2000) and Næss (2015) are a few among several influential studies that have documented the theoretical grounds as to how and why built environment has causal influence on travel behavior.

On the empirical front, residential distance from the city center has been found to exert a consistent positive influence on the extent of car use (Næss, 2011; Zegras, 2010; Zhang, Hong, Nasri, & Shen, 2012) while high local density has been found to promote non-motorized travel. Jobs located at high-density destinations generate a large proportion of commutes by transit (Næss, 2012). Similarly, Cervero and Kockelman (1997) found that mixed development, density and pro-walking design elements discourage car use and promote non-motorized travel. Still, the influence of density on travel behavior is to some degree conditional on size of the area studied (Næss, 2011; Zhang et al., 2012).

Progress in behavioral and empirical modeling in travel research during the last decades has shed light and amended issues that were major sources of inconsistencies in many empirical studies. Two of the most prominent sources of inconsistency across studies are issues related to geographic scale and residential self-selection. The problem related to geographic scale is primarily an empirical problem and has two sources. The first relates to the aggregation of geographic data and is known as the modifiable areal unit problem (MAUP). Aggregation of spatial data can often make empirical results sensitive to the way spatial boundaries or zones are defined (as the basis for aggregation) resulting in inconsistent parameter estimates (Hong et al., 2014).

The second scale-related problem is associated with the spatial uncertainty about the actual geographic areas that exert causal influences (Kwan, 2012). This is distinct from MAUP and is known as uncertain geographic context problem (UGCoP). Arbitrarily delimiting a certain location in a continuous urban settlement and analyzing it independent of the wider urban context it is part of, presents certain challenges. Neighborhood-scale studies usually give a higher relative weight to built environment factors around residence and less attention to relevant attributes associated with important destinations further away from place of residence such as work commutes (Crane & Guo, 2012). Considering that individuals in contemporary high-mobility and specialized societies tend to choose among facilities within a wider acceptable travel distance rather than choosing the closest single facility of a category (Næss, 2011, 2013) , neglecting geographic scale related issues could lead to serious inconsistencies in research findings.

The availability of agent-based disaggregate data with high geographic resolution solves empirical challenges associated with MAUP (Fotheringham, 1989). Likewise, UGCoP is mainly addressed by adopting empirical models where neighborhood as well as city-scale variables are integrated in to the same analysis. Considering accessible destinations by mode as well as city-scale variables such as residential distance from the city center has the potential to avoid biases resulting from not including a significant part of the agent's activity space. This paper employs disaggregate neighborhood and city-scale variables. Population density is measured for 250mx250m grid cells containing the residence. Moreover, residential distance from the city center is measured along the road network for each residential unit (respondent) using Arc Map.

The second problem that has been the subject of intense debate during the last decade is residential Self-selection (RSS). The discussion on the magnitude of causal influence between built environment and travel behavior has been revolving around the issue of RSS. RSS refers to the assumption that individuals choose their residential location based on their travel preferences. A strong tendency for RSS means that travel attitude confounds the relationship between built environment and travel behavior and therefore has to be controlled for in empirical analyses, as do many studies (Cao & Cao, 2014; Circella, Mokhtarian, & Handy, 2008; Frank, Saelens, Powell, & Chapman, 2007; Handy, Cao, & Mokhtarian, 2006; Kitamura, Mokhtarian, & Laidet, 1997). The working assumption in controlling for RSS has been that the effect of built environment on travel behavior will be biased upwards if RSS is not accounted for.

However, recent theoretical and empirical studies indicate that controlling for RSS can also lead to underestimation of the true built environment effects (Cao & Chatman, 2016; Chatman, 2009, 2014; Næss, 2009). Furthermore, some recent studies question the magnitude and significance of the influence of travel attitudes on residential location decisions. Næss (2009, 2014), for example, presents empirical as well as theoretical grounds showing that RSS does not significantly bias the effect of built environment on travel behavior. Ettema and Nieuwenhuis (2017), on their part, found RSS and built environment to be marginally confounding as strong travel preferences translate only weakly into residential selection. Also, studies that looked into the relative priority of various factors in residential location choice found travel preference to be second-tier as a selection criteria in residential location choice (Cao, 2008; Filion, Bunting, & Warriner, 1999; Wolday, Cao, & Næss, 2018).

A sound theory is antecedent to sound empirical models (Kendall & Stuart, 1961). Although controlling for RSS has been standard practice in land-use and travel behavior studies during the last couple of decades, this paper assumes the role of RSS in discounting the influence of built environment on car driving distance in the context of a small city to be marginal at best. Because of the smaller geographic size, the average distance to facilities within the small-city limits is relatively short and the diversity of transit services or hindrances to car use is limited. Nonetheless, residential preferences may represent individual heterogeneities that are correlated with built environment characteristics, which can have implications for car driving distance (confounding effect). Therefore, this paper will address whatever little effect self-selection might have, by explicitly specifying residential preferences in its analytical model and thereby empirically sorting out potential confounding effects.

Despite the immense research focus on the built environment-travel behavior relationship and advances in modeling it during the last decade, external validity considerations seem to have received limited attention. To my knowledge, the few studies that set out to address external validity such as Ewing et al. (2014) limit themselves to harmonizing types of built environment variables and the measurement methods employed. Differences in city size across study areas and how that influences the relationship between built environment and travel behavior are rarely addressed.[3] The few studies (Sun, He, Zhang, & Wang, 2016; Zhang et al., 2012) that have addressed this, show that the effectiveness of many built environment attributes in reducing driving distance is conditional on city size.

This study intends to fill the void in the literature by employing disaggregate data obtained from three Norwegian small cities and considering the local as well as the regional structural contexts in which the cities are embedded.

4 Data description

The scope of the study is limited to small cities with populations in their continuous built-up area ranging between 10 000 and 20 000 inhabitants (Table 1). The data was collected using a web survey from three small cities: Kongsvinger, Jessheim and Drøbak in the municipalities of Kongsvinger, Ullensaker and Frogn, respectively. In larger cities, the continuously built-up area often outstretches the administrative areas and include more than one jurisdiction. In small cities however, the continuous built-up area is often smaller than the administrative zone to which it belongs. The three cities discussed here are administrative centers of their respective municipalities and the built-up areas do not outstretch the municipal borders.

Table 1: Aggregate description of survey areas

Settlement areas (cities)	Number of residents	Area (km²)	Density (residents/ km²)	Share of municipal population
Drøbak	13405	5.52	2428.4	86 %
Jessheim	16595	6.84	2426.2	51 %
Kongsvinger	11969	7.87	1520.8	67 %

Source: Statistics Norway, population in urban settlements, 2015.

The three cities are comparable in terms of population size. Kongsvinger, on the other hand, stands out with a lower population density.

[3] The study by Ewing et al. (2014) does control for likelihood of intraregional clustering of households using hierarchical linear models but does not analyze further the patterns and potential travel behavioral effects of the clustering.

Drøbak and Jessheim are located at a comparable distance from Oslo, at respectively 39 and 45 kilometers away from the city center of Oslo along the road network at opposite ends of the Oslo metropolitan area. Both cities are connected to Oslo with well-functioning road networks. The two cities do differ, though, in terms of railway infrastructure linking them to Oslo. Jessheim is integrated into the rail network with scheduled train departures to Oslo every half hour while Drøbak is not integrated into the rail network. Compared to Drøbak and Jessheim, Kongsvinger is located further away from Oslo, at a distance of 96 kilometers along the road network. Kongsvinger is integrated into the rail network and has an hourly scheduled train departure to Oslo.

4.1 Center structure and regional context of the cities

The three small cities represent three different urban structural conditions both locally (city center structures) as well as in their role in the urban hierarchy in the wider regional context. Jessheim and Drøbak are closer to Oslo than Kongsvinger and hence more integrated in the Oslo metropolitan labor market.

Built environment variables are classified into three categories depending on the geographic scale considered. One, neighborhood scale refers to built environment attributes within the vicinity of the residence. Neighborhood scale refers here to an area within about a kilometer of a residence. Population density is the only neighborhood variable included in this paper. Population density is calculated for a 250m x 250m grid containing the residence. Two, local scale refers to built environment variables that are within the bounds of the particular small city. Local scale variables in this article primarily include job density (which is calculated for an area within 2 km of the residence), residential distance from the city center and city center structure (polycentric vs monocentric). The local scale also includes neighborhood-scale variables. Three, regional scale refers to variables reflecting regional spatial interactions as a result of a city's level in the urban hierarchy in a regional context. Centrality and distance to the nearest higher-order city are two regional variables considered in this paper.

The centrality variable is defined using commuter flow patterns (Aguilera & Mignot, 2004). Commuter flows between the case cities and the adjacent urban areas characterizes the small cities as either regional centers or satellites. Kongsvinger, with its secluded location away from regional influences of other major cities, has a smaller proportion of its resident labor force out-commuting. In 2015, 71% percent of the resident labor force in Kongsvinger municipality were locally employed whereas the corresponding figures for the municipalities containing Drøbak and Jessheim are about 37 and 49 percent, respectively.[4] On the basis of commuter flow data and proximity to a higher-order urban area, Kongsvinger is defined as regional center while Drøbak and Jessheim are defined as satellites. Table A2 in the appendix summarizes commuter flow pattern for the sample.

Apart from the regional structural disparities, the three cities also differ in the way the city centers are structured. Drøbak city has two competing centers. The city market (Torget) close to the harbor is traditionally considered as the main city center. The second center, AMFI-Drøbak, is a recent development with shopping centers and other service-rendering facilities at the outskirt of the city. Both centers have a significant number of facilities but the largest shopping facilities are located at AMFI-Drøbak. The two centers are about 3 kilometers apart. Jessheim and Kongsvinger, on the other hand, have monocentric urban structures with most of the commercial and other service facilities concentrated in the city center.

The contrast in center structures is reflected by the distribution of facilities in the three cities as shown by Figure 1. The vertical axis shows the cumulative accessibility to facilities while the horizontal axis represents residential distance (in kilometer) from the city center.

[4]Statistics Norway, register based employment data, 4th quarter, 2015.

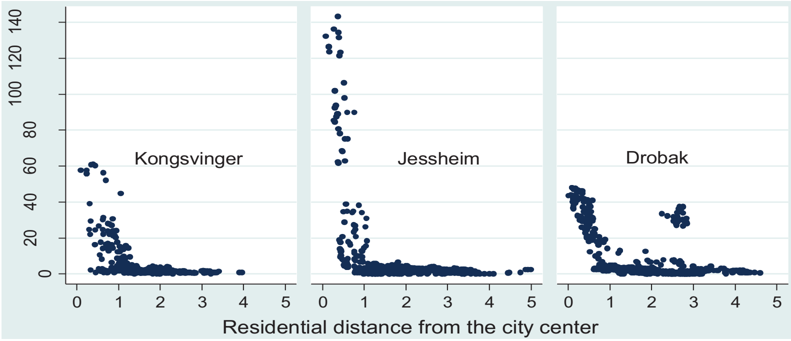

Figure 1: Distribution of accessibility to facilities[5] in the cityscapes

4.2 The survey

The survey was conducted using a self-administered web-questionnaire. The sampling frame was residential units in the continuous built-up area of the three cities. An adult between the age of 18 and 75 was randomly selected from each residential unit resulting in a sample of 4591, 5609 and 5074 potential respondents for Kongsvinger, Jessheim and Drøbak respectively. Response rates for travel surveys nowadays often range between 10 and 20 percent (Hjorthol, Engebretsen, & Uteng, 2014; Næss, 2016). To mitigate the continuously declining response rates in Norway and elsewhere (Amundsen & Lie, 2013), I included in my gross sample more than 90 percent of the residential units within the continuous built-up area in each of the three cities.

An invitation letter was sent to each potential respondent in December 2015 with information on the purpose of the survey, how to access and complete the survey and contact information. The survey did not use follow-ups in the form of reminders.[6] The response rates were 11.1%, 11.0%, and 16.6% for Kongsvinger, Jessheim and Drøbak, respectively. Although the response rates were low, they are within the mainstream and hence typical for surveys administered to the general population. The net sample reflects the population characteristics with minimum skewness, as reported in Table 2.

Sample demographic characteristics such as household size, average number of children per household, average number of dependents 17 years of age and below, average age of respondents, and gender proportions conform well to their population counterparts in all three cities. On the socio-economic factors, respondents with college education or above seem to be overrepresented. I believe, however, that the disparity is lower than what appears in Table 2 for the following two reasons. The values are calculated slightly differently between the sample and the population. The proportion of respondents with college education in the sample shows the share of college educated individuals in the age bracket of 18 to 75 years. For the municipalities, it is calculated for the population subgroup 16 years or older. Besides, a higher proportion of individuals with college education live in the cities, raising the city average compared to the municipality average. Average household income is also slightly skewed towards higher income individuals, but the difference between the sample and population average is likely to be lower than reported above due to the above two reasons. The employed share of the labor force in the sample mirrors the population average fairly well.

[5]Accessibility to facilities is calculated based on gravity model. The facilities comprise of grocery stores, medical facilities (medical clinics, dental clinics and pharmacies), restaurants and cafés, facilities for errands other than grocery stores, and fitness centers.

[6]To incentivize participation, respondents who completed the survey were eligible for a gift card lottery worth 6,000 NOK (approx. USD 750).

Table 2: Comparison of key indicators between survey data and the population from which the sample was drawn

	Kongsvinger (N=507)	Municipality of Kongsvinger	Jessheim (N=616)	Municipality of Ullensaker (includes Jessheim)	Drøbak (N=843)	Municipality of Frogn (Includes Drøbak)
Average household size	2.13	2.05	2.51	2.34	2.50	2.27
Average number of children per household	0.46	0.40	0.65	0.59	0.60	0.51
Proportion of children aged 0-17	22.0 %	18.9 %	25.8 %	24.8 %	24.2 %	22.0 %
Average respondent age (18<=age<=75yrs)*	52.0	47.3	48.7	43.7	52.0	47.0
Gender (Share of female)*	46.8 %	51.3 %	51.0 %	49.4 %	53.3 %	51.4 %
Education level (Share of college level education)	54.2 %	21.6 %	59.2 %	25.9 %	66.5 %	35.0 %
Proportion employed	66.3 %	56.7 %	74.5 %	68.8 %	72.2 %	66.8 %
Average household income (1,000 NOK)	756	508	854	571	893	583

*Gender (Proportion of female) is calculated for the sampling frame, i.e., section of the population>=18 years old

5 Analytical model

The empirical model employed is a multivariate analysis involving multiple linear regression and a logistic regression. First, car driving distance [7] is regressed linearly on the list of independent variables to investigate the influences of neighborhood, local and regional built environment attributes on car driving distance. Regional influence is modeled by introducing a centrality variable and interacting it with residential location. Second, a binary logistic regression of commuting modes is employed to explore the causal pathways through which residential location influences local and regional car driving distance. The independent variables include built environment attributes (residential distance from the city center, job density and population density), demographics (gender, household size, respondent's age and number of children below 18 years), socioeconomic variables (employment status, education level and income) as well as five residential preference factors (discussed in detail in Section 5.1). An exhaustive list of variables is presented in Appendix 1.

The models are estimated stepwise. To begin with, car driving distance is modeled as a function of a single independent variable, the residential distance from the city center. Additional variable groups of demographic, socioeconomic and other built environment characteristics are then added sequentially into the model. Control variables related to residential preference are also included by the end of the recursive estimation process. At each step, estimates that are significant at a 10% level are retained. At the final stage of the estimation, only estimates that are significant at 5% level are reported.

Metric values such as car driving distance and residential distance from the city center are transformed into logarithmic form. Strictly positive values have conditional distributions that often are positively skewed (heteroskedastic). A log transformation mitigates this problem. Log transformation also tends to make ordinary least square regression estimates less sensitive to outlying or extreme values (Wooldridge, 2014).

[7]Car driving distance, as used here, refers to total distance traveled by car with the respondent as a driver. The concept of car refers to automobiles primarily used for personal transport. Ordinary cars, Light pick-up trucks, and other small vehicles used for personal mobility fall in to this category.

A city's place in a center hierarchy, positions a city in the context of regional socio-cultural and economic life. As such, regional physical attributes are likely to influence individuals' travel decisions. To reflect the effect of regional conditions on car driving distance, two regional variables are defined, namely the centrality variable as well as an interaction term between centrality and residential distance from the city center. The centrality variable, a dichotomous variable, is defined based on whether a city is a satellite or a regional center (see Section 4.1). The centrality dummy assumes the value "1" for the regional center and "0" otherwise. The rationale for the interaction between the centrality dummy and residential distance from the small-city center, is to test how regional context influences the effect of residential location on driving distance.

5.1 Factor analysis

To account for individual heterogeneities due to residential preference, factor variables are extracted from a wide-ranging battery of 4-scale Likert items. In the survey, respondents were asked to indicate the importance of 21 housing and neighborhood characteristics when they were looking for a place to live (or if they were to move to a new dwelling) on a four-point scale from "not at all important" (1) to "highly important" (4).

Likert item-based measures of stated preferences are known to be highly correlated as many of those items measure similar underlying factors. Replacing the preference items with components generated through factor analysis does not only eliminate a potential serial correlation but also compresses the items to the essential underlying factors. Using component factor analysis, the residential preference items are compressed to five factors in two steps. In step one, an exploratory factor analysis on the whole set of 21 preferences generated seven factors. Then, preferences that load on the first five factors were retained using a scree plot.[8] In step two, the same process was repeated again on the retained preference items [9] generating the results reported in Table 3.

[8]Due to low loading, four items (low housing cost, proximity to family and friends, architectural quality and familiar neighborhood) were dropped

[9]Further two preference items, namely proximity to train station and proximity to bus stop were dropped in step two due to conceptual interpretability.

Table 3: Factor analysis of residential preferences and their loading patterns

	Shopping	Family	Amenities	Investment	Exercise
Eigenvalue	2,543	1,716	1,600	1,597	1,469
Proximity to other shopping facilities	0,819				
Proximity to grocery stores	0,790				
Easy access to shopping mall	0,750				
Proximity to the city center	0,718				
Good school/kindergarten		0,760			
Private garden		0,649	0,494		
Proximity to workplace		0,594			
Good property management	0,322	-0,461		0,451	0,330
Undisturbed location			0,702		
Nice view			0,613		
Distance to major road/rail line			0,414	0,315	
Favorable investment object				0,729	
No social problems				0,716	
Opportunities for physical exercise					0,826
Proximity to green areas			0,390		0,735

Notes: 1. Extraction Method: Principal Component Analysis. Variance maximizing rotation (Varimax) was used with Kaiser Normalization. Extraction was based on eigenvalue greater than "1". Factor loadings smaller than 0.30 were suppressed. 2. Total variance explained is 59.5%

6 Results and discussion

6.1 How important is regional hierarchy in influencing car driving distance?

One of the research questions this paper intended to address is how the regional context influences driving distance and whether the effect of residential location on driving distance varies depending on regional context. To address these questions, a multivariate regression of car driving distance is modeled on built-environment, socio-economic, demographic, residential preference and regional variables. Data from the three small cities are pooled together for this analysis. Table 4 presents model results.

A city's regional context (centrality) has a bearing on car driving distance. Controlling for the other investigated variables, residents of a city that is a regional center (Kongsvinger) drive about 35% shorter distance than those in the satellite cities (Jessheim and Drøbak) do.

Among the local built environment variables, only residential location is significant. Living far away from the city center is associated with longer car driving distances. Due to the interaction term between centrality and residential location, the net effect of residential location has two components: the independent effect and the interaction effect. The interaction effect, which shows how the effect of residential location varies depending on whether a small city is a satellite or not, is weakly significant. The net effect (sum of the independent effect of residential location and the effect of the interaction term) of residential location is therefore more than twice as high in Kongsvinger as in Jessheim and Drøbak. For Kongsvinger, the effect is in line with the literature (Boarnet, Nesamani, & Smith, 2003; Ewing & Cervero, 2010; Næss, 2005; Pushkar, Hollingworth, & Miller, 2000; Stevens, 2017; Zegras, 2010) whereas it is significantly lower for the satellites.

Table 4: City-scale and regional effects on car driving distance

	Coefficients	Robust std. err.	P-value
Log of residential distance from the city center (km)	0.1051	.0471	0.026
Gender (male)	0.5355	.0644	0.000
Household income per adult (1000 NOK)	0.0008	.0002	0.000
Employment	0.4453	.0780	0.000
Investment factor	0.0891	.0329	0.007
Centrality	-0.3513	.0934	0.000
Centrality X residential location[10]	0.1763	.0957	0.066
Constant	3.6849	.0968	0.000
R-squared	0.1387		
Number of observations	1356		

Note: The results are based on pooled data from the three small-cities.

Neighborhood built environment attributes (job density and population density) show no effect on car driving distance. This is as expected and conforms to previous findings (Ewing & Cervero, 2010; Kockelman, 1997). Among the socio-demographics, gender and employment status exert significant influence, with men driving 54% longer than women and the employed 45% longer than those who are not workforce participants. Income is also statistically significant but smaller in effect size, but this is partly because I have also controlled for employment.

6.2 How significant is regional context and city center structure in the relationship between residential location and car driving distance?

City center structures and regional context are relevant spatial structures influencing travel decisions. As suggested by the centrality variable and the interaction term between centrality and residential location (Section 6.1), the regional location of a small city has significant implication for the relationship between built environment and car driving distance. To highlight the effect of varying regional context on the relationship between built environment (neighborhood and city-scale variables) and travel behavior, a separate model is developed for each city.

6.2.1. Kongsvinger city

Regressing the log of car driving distance on residential distance from the city center and recursively controlling for demographic, socio-economic, neighborhood built environment attributes and residential preferences yields only four significant variables among which residential distance from the city center is the only built environment variable. Table 5 presents summary of the results.

Residential distance from the city center has an elasticity of 0.26, which is within the mainstream of the literature. Residents who live closer to the city center of Kongsvinger, overall, tend to have fewer total kilometers driven. Built environment attributes at the neighborhood scale, on the other hand, show no influence on car driving distance, which is also in accordance with the mainstream in the literature (Kockelman, 1997; Næss, 2012).

[10]Interaction term between the centrality dummy and the log of residential distance from the city center.

Among the demographic and socio-economic variables, only gender and employment were found to be influential. The literature conforms widely in that men drive longer distances on average (Hjorthol, 2003, 2008; Zegras, 2010). Similarly, employees, due to their daily commutes, are expected to drive longer distances than those who are not workforce participants. The other two important socio-economic attributes included in the analysis are income and education. Both are insignificant.[11] Income remains insignificant when employment and education are not controlled for.

Table 5: Multiple regression analysis of total car driving distance for the city of Kongsvinger

	Coefficients	Robust std. err.	P-value
Log of residential distance from the city center (km)	0.2645	0.0801	0.001
Gender (male)	0.6622	0.1233	0.000
Employment	0.3878	0.1232	0.002
Investment factor	0.1277	0.0618	0.040
Constant	3.7588	0.1271	0.000
R-squared	0.1284		
Number of observations	361		

Note: 1. Dependent variable: Log of car driving distance (km). 2. Job density (number of jobs in a 2 kilometer radius from the residence) is dropped due to high correlation with residential distance from the city center (r=0.91). Another important reason for its exclusion also relates to micronumerosity. Central urban locations capture the same jobs reducing the variability between observations for that particular variable.

The effect of residential distance from the city center on car driving distance is robust even after controlling for transit commutes (Table 8). This result is an indication that people residing closer to the city center have shorter car driving distance not only because of their tendency to utilize transit but also primarily due to the distance-minimizing effect of the built environment. As a regional center, Kongsvinger employs a substantial proportion of the resident workforce locally, about 72% for the sample and a comparable 71 per cent for the population in the municipality. This helps reduce regional commuting pattern and overall commuting distances. Lower regional commuting pattern, in turn, is likely to boost the effect of local built environment factors such as residential distance from the city center.

From the residential preference variables, the investment factor is positively associated with driving distance. The result is not counterintuitive as the investment factor may represent consumerism-oriented attitude that might manifest itself as higher levels of driving.

6.2.2 Drøbak city

The regression model for Drøbak, besides the built environment variables specified in Section 5, includes residential distance to the second center, AMFI-Drøbak. Model results are presented in Table 6.

[11]Theoretically, income may influence travel behavior directly by easing capability constraints and in ways that are more complex such as inducing individuals to adopt a certain lifestyle, which then can have a trickle-down effect on travel behavior. Despite the strong underlying arguments, income has no effect on driving distance at a 5% significance level even when employment and education are controlled for. Nonetheless, the findings fit well into the narrative of the small city as being secluded from immediate regional influences. The high affluence (average income) among the populace means there is less variability in access to mobility resources.

None of the built environment variables, including residential distance from both centers, have significant influence on car driving distance.

In the literature, residential distance from the city center is established as the built environment variable with strongest influence on car driving distance. The most recent comprehensive reviews put the weighted elasticities of the variable at 0.34 (Stevens, 2017) and 0.22 (Ewing & Cervero, 2010). The likely explanation for the dissociation in Drøbak of residential distance from both centers and total driving distance is the result of at least two main mechanisms. First, the dispersal of facilities away from the city center weakens the city center as a hub of local travel. Second, regional influence. Drøbak is at the outer edge of the Oslo metropolitan region. As a result, a large proportion of its resident labor force commutes to Oslo. The longer commuting distance hence dwarfs (as a share of total travel distance) whatever gains the local environment may be able to induce in terms of short driving distances and non-motorized travel.

Table 6: Multiple regression analysis of total car driving distance for the city of Drøbak

	Coefficients	Robust std. err.	P-value
Gender (male)	.6382545	.0973776	0.000
Household income per adult (1000 NOK)	.0008127	.0002657	0.002
Employment	.3693339	.1221669	0.003
Investment factor	.1282386	.0477896	0.007
Family factor	.1095918	.050912	0.032
Constant	3.726962	.1464115	0.000
R-squared	0.1394		
Number of observations	595		

Men and the employed have significantly longer total driving distances. Total driving distance for men is 64% longer than for women. Correspondingly, the employed have 37% longer driving distance than the unemployed. The effect of gender and employment on car driving distance is as expected and conforms with the literature. Employed individuals tend to travel longer due to daily commutes than those that are not. In addition to gender and employment status, higher levels of income also tend to lead to higher driving distances. Among the residential preference factors, the investment factor and family factor are significant with expected signs.

6.2.3. Jessheim

As with the other two cities, multivariate regression with the same model specification and recursive estimation method was repeated for the city of Jessheim. Results are reported in Table 7.

Among the built environment variables, residential distance from the city center has the expected sign and is significantly associated with total car driving distance. Population density also appears to have a positive association with car driving distance, indicating that more densely populated areas initiate higher car driving distance. The sign reversal is an anomaly, nonetheless, opposite to what is widely documented in the literature. One plausible explanation for this could be the non-continuous clusters of residential development around the city of Jessheim. Moreover, individuals often have to drive through the central part of Jessheim to connect to the highway passing through Jessheim.

Table 7: Multiple regression analysis of total car driving distance for the city of Jessheim

	Coefficients	Robust std. err.	P-value
Log of residential distance from the city center (km)	0.1696	0.0807	0.036
Gender (male)	0.2972	0.1103	0.007
Household income per adult (NOK 1000)	.0016	0.0003	0.000
Employment	0.4919	0.1435	0.001
Population density	0.0013	.0006	0.040
Constant	3.1544	.1954	0.000
R-squared	0.1688		
Number of observations	437		

From the socio-economic and demographic characteristics, gender, employment and income are significant with associated semi-elasticities of 0.30, 0.49 and 0.0016 respectively. Controlling for the other investigated variables, men have 30% longer driving distances than women and the employed 49% percent longer than the unemployed, while increasing annual gross income by NOK 10 000 leads to an increase in driving distance by about 16%. Employment obviously has the highest impact on car driving distance due to the tendency for skilled workers to commute to Oslo similar to what is observed in the city of Drøbak. None of the residential preference indicators is significant in the model for Jessheim.

There are at least three ways by which local-scale built environment attributes can influence total car driving distance. One, by influencing the extent of active travel; two, by influencing the number of local and regional transit commutes; and three, by contributing to shorter trip distances (car driving distance) in the local action space. The following section addresses the likely pathways through which residential distance from the city center influences total driving distance. The relationship between a small-city's built environment and active travel is discussed in detail in another article (Wolday, 2018, under review) and will therefore not be addressed here.

6.3 How resilient is the effect of local built environment on total driving distance in the face of regional influence?

The effect of residential distance from the city center on car driving distance is both positive and significant in the cities of Jessheim and Kongsvinger (Tables 5 & 7). This, however, does not tell whether the relationship characterizes regional influence, influence due to local-scale structural conditions or both. Is the influence of residential location on driving distance due to the local city center being an attractive destination or is it regional pull factors outside the local city's domain that are more influential? To sort out the local from the regional effects, a transit dummy is introduced to the significant estimates in Tables 5, 6 and 7. The transit dummy is a dichotomous variable representing commuting by transit three or more days a week. Table 8 summarizes results that are significant at 5% level.

Commuting by transit three or more days a week turned out to have highly significant effect on car driving distance in all three cities but the effect size is greater in Jessheim and Drøbak. Commuting by transit reduces driving distance on average by the extent of 49%, 65% and 71% for Kongsvinger, Jessheim and Drøbak, respectively, ceteris paribus.

More importantly, the introduction of the transit dummy causes residential location from the city center to be insignificant in the city of Jessheim. In Kongsvinger on the other hand, the effect of residential location remains unchanged despite controlling for transit commutes. In the case of Drøbak, residential location was insignificant prior to controlling for commuting by transit (Table 6).

Looking at the relationship between residential location, regional context and transit commutes, the influence of residential location on car driving distance can be deduced to be indirect. Residential location influences commute mode choice for regional transport with residential distance from the city center acting as proxy for access to transit, more specifically distance to the transit station.

Table 8: The resilience of residential distance from the city center when commuting by transit is accounted for

	Kongsvinger		Jessheim		Drøbak	
	Coefficients	**P-value**	**Coefficients**	**P-value**	**Coefficients**	**P-value**
Log of residential distance from the city center (km)	0.2828	0.008		*insig*		*insig.*
Gender (male)	0.6894	0.000	0.4160	0.000	0.5853	0.000
Household income per adult (NOK 1000)		*insig.*	0.0016	0.000	0.0010	0.000
Employment		*Insig.*	0.8793	0.001		*Insig.*
Commuting by transit	-0.6643	0.000	-1.0521	0.000	-1.2400	0.000
Constant	3.1977	0.000	3.2339	0.000	4.3795	0.000
R-squared	*0.1061*		*0.2521*		*0.2901*	
Number of observations	*254*		*347*		*469*	

Note: The commuting by transit variable was added to the significant estimates reported in Tables 5, 6, & 7 above. In the city of Drøbak, employment is insignificant as a result of controlling for income.

Higher income appears to induce longer driving distances in Jessheim and Drøbak whereas it is insignificant in Kongsvinger. This is likely related to regional influences, that is, higher concentration of specialized jobs in Oslo leading for skilled and well remunerated workers to tend to commute to Oslo. Conversely, less skilled, low-earning workers are likely to take up local jobs, as longer commutes may not be fully compensated. The effect of employment is also stronger in Jessheim and Drøbak mainly due to the longer average commuting distances in both cities.

To back the claim that reduction in car driving distance in Jessheim is due to centrally located commuters choosing to commute by train instead of a car, a logistic regression provides a more direct measure of association between train commute and residential location. Table 9 presents results from a logistic model of commuting by train at least three times a week for commuting distances exceeding 20 kilometers on the usual independent variables specified in the linear regression models above.

Table 9: Likelihood of commuting by train at least 3 days a week among Jessheim respondents

	Coefficient	**Robust std. err.**	**Elasticity**	**P-value**
Log of residential distance from the city center	-0.6462	.2265	-0.2649	0.004
Constant	-0.0352	.1913		0.852
Nagelkerke R^2	*0.051*			
Number of observations	*227*			

Note: the independent variables in the models include demographics (age, household size, responsibility for transporting children), socio-economic (education, income, employment), built environment (residential distance from the city center, population density, job density) and residential preference factors (shopping, amenities, investment, family and exercise). Summary statistics for the variables related to the model are reported in Table A3 under the appendix.

Although the model has lower coefficient of determination (Nagelkerke R^2), the model as a whole is significant. Only one variable is significant in the model. Residential distance from the city center is negatively and significantly associated with the likelihood of commuting by train. As residential distance from the city center increases from 1 km to 3 km, the probability of commuting by train declines by 0.17. A further increase in residential location from the city center from 1 km to 5 km would correspondingly decrease the probability of commuting by train by 0.24.

7 Conclusion

This article discusses the association between built environment characteristics and car driving distance in a small city context. It started out with the question about whether residential distance from the city center influences car driving distance and whether there is a local or regional dimension to that association.

Survey data from three small cities, namely Kongsvinger, Jessheim and Drøbak, were analyzed. The results underscore that regional context is an important denominator on how and to what extent the influence of the distribution of settlement locations is reflected on travel behavior in a small city context. In a city such as Kongsvinger, where regional pull-factors from a nearby higher-order city is weaker, proximity to the city center significantly reduces total car driving distance. In cities with proximity to a higher-order city, the influence of distance from the city center on driving distance is weaker and likely mediated by transit commutes.

Among the demographic and socio-economic characteristics, gender has a consistently strong influence on car driving distance whereas income and employment are strongest where regional characteristics are influential.

The contribution of any practice-oriented planning research is ultimately measured by how informative it is for the planning practice on the ground. This article tried to shed light on two issues with policy implications: Which policy options are likely to reduce car driving distance originating from small cities? Can densification be a viable guiding principle for urban spatial development in small cities?

Reducing car driving distance originating from a small city may require a combination of policy options geared at the local city-scale travel and regional travel. For local travel, reducing the average distance from the city center would reduce car driving distance. At the regional scale, efficient transit with high average accessibility (with a station at the center of the city) would also reduce car driving distance.

On the issue of densification in small cities, this paper answers the question only partially. The analysis at a local scale shows that proximity to the city center in a monocentrically structured city reduces travel distance by car as well as increases the likelihood of commuting by transit. Hence, densification in and close to the city center can contribute to reducing car driving distance. However, due to the small geographic size, the sustainability potential of small cities lies in fostering travel by active modes. Consequently, the effect of relevant local built environment factors such as accessibility to and dispersal of facilities as well as design features such as street network on active travel have to be explored to give a more nuanced answer.

Small cities are often cash strapped because they lack economies of scale associated with administrative costs while at the same time having a limited taxable population and business base. In such conditions, the push to adopt expansionary spatial development may be more appealing as opposed to densifying at city centers. The question that begs answering is therefore, do small municipalities (cities) have the economic incentive to densify? Future study on the economic viability of densification can help clarify on the incentives to utilize central-city locations for development.

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[12]Residential distance from the city center is also strongly negatively associated with commuting by transit (bus and train). I chose to run the model with one mode, train commutes, because the train station is located at the city center. Moreover, train is used primarily for regional commutes.

References

Aguilera, A., & Mignot, D. (2004). Urban sprawl, polycentrism and commuting. A comparison of seven French urban areas. *Urban Public Economics Review, 1*, 93–113.

Amundsen, B., & Lie, E. (2013). Do surveys still give an accurate picture? Fewer willing to participate in surveys. Retrieved from: https://www.forskningsradet.no/en/Newsarticle/Fewer_willing_to_participate_in_surveys/1253986812629

Bhat, C. R., & Guo, J. Y. (2007). A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. *Transportation Research Part B: Methodological, 4*1(5), 506–526. doi:http://dx.doi.org/10.1016/j.trb.2005.12.005

Boarnet, M., & Crane, R. (2001a). The influence of land use on travel behavior: Specification and estimation strategies. *Transportation Research Part A: Policy and Practice, 35*(9), 823–845. doi:http://dx.doi.org/10.1016/S0965-8564(00)00019-7

Boarnet, M., & Crane, R. (2001b). *Travel by design: The influence of urban form on travel.* Oxford: Oxford University Press.

Boarnet, M., Nesamani, K., & Smith, S. (2003). *Comparing the influence of land use on nonwork trip generation and vehicle distance traveled: An analysis using travel diary data.* Irvine, CA: University of California Irvine, Center for Activity Systems Analysis.

Cao, J., & Cao, X. (2014). The Impacts of LRT, neighborhood characteristics, and self-selection on auto ownership: Evidence from Minneapolis-St. Paul. *Urban Studies, 51*(10), 2068–2087. doi:10.1177/0042098013505887

Cao, X. (2008). Is alternative development undersupplied? Examination of residential preferences and choices of Northern California movers. *Transportation Research Record: Journal of the Transportation Research Board, 2077*, 97–105. doi:10.3141/2077-13

Cao, X., & Chatman, D. (2016). How will smart growth land-use policies affect travel? A theoretical discussion on the importance of residential sorting. *Environment and Planning B: Planning and Design, 43*(1), 58–73. doi:10.1177/0265813515600060

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009). Examining the impacts of residential self-selection on travel Behavior: A focus on empirical findings. *Transport Reviews, 29*(3), 359–395. doi:10.1080/01441640802539195

Cao, X., Næss, P., & Wolday, F. (2017). Urban containment and inner-city densification reduce auto ownership. Paper presented at the WSTLUR symposium, July 3–6, 2017, Brisbane, Australia.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2*(3), 199–219. doi:http://dx.doi.org/10.1016/S1361-9209(97)00009-6

Chatman, D. G. (2009). Residential choice, the built environment, and nonwork travel: Evidence using new data and methods. *Environment and Planning A, 41*(5), 1072–1089. doi:10.1068/a4114

Chatman, D. G. (2014). Estimating the effect of land use and transportation planning on travel patterns: Three problems in controlling for residential self-selection. *Journal of Transport and Land Use, 7*(3), 47–56.

Cho, G.-H., & Rodríguez, D. A. (2014). The influence of residential dissonance on physical activity and walking: Evidence from the Montgomery County, MD, and Twin Cities, MN, areas. *Journal of Transport Geography, 41*, 259–267. doi:http://dx.doi.org/10.1016/j.jtrangeo.2014.06.007

Christaller, W. (1966). Central places in southern Germany. Englewood Cliffs, NJ: Prentice-Hall.

Circella, G., Mokhtarian, P. L., & Handy, S. L. (2008). Land use, attitudes, and travel behavior relationships: A cross-sectional structural equations model for Northern California. Paper presented at the

Transportation Research Board 87th Annual Meeting, Washington, DC.

Crane, R., & Guo, Z. (2012). Toward a second generation of land-use/travel models: Theoretical and empirical frontiers. In N. Brooks, K. Donaghy, & G. Knaap (Eds.), *The Oxford handbook of urban economics and planning* (pp. 522-544). Oxford: Oxford University Press.

Ellegård, K., & Vilhelmson, B. (2004). Home as a pocket of local order: Everyday activities and the friction of distance. Geografiska Annaler: Series B, *Human Geography, 86*(4), 281–296. doi:10.1111/j.0435-3684.2004.00168.x

Ettema, D., & Nieuwenhuis, R. (2017). Residential self-selection and travel behavior: What are the effects of attitudes, reasons for location choice and the built environment? *Journal of Transport Geography, 59*, 146–155. doi:10.1016/j.jtrangeo.2017.01.009

Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American Planning Association, 76*(3), 265–294. doi:10.1080/01944361003766766

Ewing, R., Tian, G., Goates, J. P., Zhang, M., Greenwald, M. J., Joyce, A., … & Greene, W. (2014). Varying influences of the built environment on household travel in 15 diverse regions of the United States. *Urban Studies, 52*(13), 2330–2348. doi:10.1177/0042098014560991

Filion, P., Bunting, T., & Warriner, K. (1999). The entrenchment of urban dispersion: Residential preferences and location patterns in the dispersed city. *Urban Studies, 36*(8), 1317–1347. doi:10.1080/0042098993015

Fotheringham, A. (1989). Scale-independent spatial analysis. In M. Goodchild & S. Gopa (Eds.), *The accuracy of spatial databases* (pp. 221-228). Abingdom, UK: Taylor & Francis.

Frank, L. D., Saelens, B. E., Powell, K. E., & Chapman, J. E. (2007). Stepping towards causation: Do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity? *Social Science & Medicine, 65*(9), 1898–1914. doi:https://doi.org/10.1016/j.socscimed.2007.05.053

Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D, 10*(6), 427–444. doi:10.1016/j.trd.2005.05.002

Handy, S., Cao, X., & Mokhtarian, P. L. (2006). Self-selection in the relationship between the built environment and walking: Empirical evidence from Northern California. *Journal of the American Planning Association, 72*(1), 55–74. doi:10.1080/01944360608976724

Hjorthol, R. (2003). Gendered aspects of travel behavior development-are the differences disappearing? Paper presented at the European Transport Conference, October 8–10, Strasbourg, France.

Hjorthol, R. (2008). Daily mobility of men and women—a barometer of gender equality. In T. Cresswell & T. Uteng (Eds.) *Gendered mobilities* (pp. 193–210). London: Routledge.

Hjorthol, R., Engebretsen, Ø., & Uteng, T. P. (2014). The Norwegian Travel Survey 2013/14 – key results. Retrieved from https://www.toi.no/getfile.php?mmfileid=39511

Hong, J., Shen, Q., & Zhang, L. (2014). How do built-environment factors affect travel behavior? A spatial analysis at different geographic scales. *Transportation, 41*(3), 419–440. doi:10.1007/s11116-013-9462-9

Kendall, M. G., & Stuart, A. (1961). *The advanced theory of statistics* (Vol. 2). New York: Charles Griffin Publishers.

Kitamura, R., Mokhtarian, P. L., & Laidet, L. (1997). A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation, 24*(2), 125–158. doi:10.1023/a:1017959825565

Kockelman, K. (1997). Travel behavior as function of accessibility, land-use mixing, and land-use balance: Evidence from San Francisco Bay Area. *Transportation Research Record: Journal of the Transportation Research Board, 1607*, 116–125. doi:10.3141/1607-16

Kwan, M.-P. (2012). The uncertain geographic context problem. Annals of the Association of American *Geographers, 102*(5), 958–968. doi:10.1080/00045608.2012.687349

Kwan, M.-P., & Weber, J. (2008). Scale and accessibility: Implications for the analysis of land use–travel interaction. *Applied Geography, 28*(2), 110–123. doi:http://dx.doi.org/10.1016/j.apgeog.2007.07.002

Milakis, D., Cervero, R., & van Wee, B. (2015). Stay local or go regional? Urban form effects on vehicle use at different spatial scales: A theoretical concept and its application to the San Francisco Bay Area. *Journal of Transport and Land Use, 8*(2), 55–86. doi:10.5198/jtlu.2015.557

Næss, P. (2005). Residential location affects travel behavior—but how and why? The case of Copenhagen metropolitan area. *Progress in Planning, 63*(2), 167–257. doi:http://dx.doi.org/10.1016/j.progress.2004.07.004

Næss, P. (2006). *Urban structure matters: Residential location, car dependence and travel behavior* (Vol. 13). London: Routledge.

Næss, P. (2009). Residential self-selection and appropriate control variables in land use: Travel studies. *Transport Reviews, 29*(3), 293–324. doi:10.1080/01441640802710812

Næss, P. (2011). 'New urbanism' or metropolitan-level centralization? A comparison of the influences of metropolitan-level and neighborhood-level urban form characteristics on travel behavior. *Journal of Transport and Land Use, 4*(1), 20. doi:10.5198/jtlu.v4i1.170

Næss, P. (2012). Urban form and travel behavior: Experience from a Nordic context. *Journal of Transport and Land Use 5*(2), 21–45. doi:10.5198/jtlu.v5i2.314

Næss, P. (2013). Residential location, transport rationales and daily-life travel behavior: The case of Hangzhou Metropolitan Area, China. *Progress in Planning, 79*(0), 1–50. doi:http://dx.doi.org/10.1016/j.progress.2012.05.001

Næss, P. (2014). Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies. *Journal of Transport and Land Use, 7*(3), 23. doi:10.5198/jtlu.v7i3.491

Næss, P. (2015). Built environment, causality and travel. *Transport Reviews, 35*(3),1–17. doi:10.1080/01441647.2015.1017751

Næss, P. (2016). Urban planning: Residential location and compensatory behavior in three Scandinavian cities. In T. Santarius, H. J. Walnum, & C. Aall (Eds.), *Rethinking climate and energy policies: New perspectives on the rebound phenomenon* (pp. 181–207). Cham, Switzerland: Springer International Publishing.

Næss, P., & Jensen, O. B. (2004). Urban structure matters, even in a small town. *Journal of Environmental Planning and Management, 47*(1), 35–57. doi:10.1080/0964056042000189790

Næss, P., Strand, A., Wolday, F., & Stefansdottir, H. (2017). Residential location, commuting and non-work travel in two urban areas of different size and with different center structures. *Progress in Planning. (In press)*. doi:https://doi.org/10.1016/j.progress.2017.10.002

Norway's Government. (2014). Central government policy guidelines for coordinated land use and transport planning in 1993, amended in 2014. Retrieved from https://www.regjeringen.no/en/dokumenter/National-Policy-Guidelines-for-coordinated-land-use-and-transport-planning/id107851/

Pushkar, A. O., Hollingworth, B. J., & Miller, E. J. (2000). A multivariate regression model for estimating greenhouse gas emissions from alternative neighborhood designs. Paper presented at the 79th annual meeting of the Transportation Research Board, Washington, DC.

Røe, P. G. (2000). Qualitative research on intra-urban travel: An alternative approach. *Journal of Transport Geography, 8*(2), 99106. doi:http://dx.doi.org/10.1016/S0966-6923(99)00039-3

Statistics Norway. (2015a). Land use in urban settlements. Area and population of urban settlements, by densely populated area, contents and year. Statistikkbanken, Table: 04859. Retrieved from http://

www.ssb.no

Statistics Norway. (2015b). Register based employment data, 4th quarter, 2015. Retrieved from https://www.ssb.no/en/arbeid-og-lonn/statistikker/regsys

Stevens, M. R. (2017). Does compact development make people drive less? *Journal of the American Planning Association, 83*(1), 7–18. doi:10.1080/01944363.2016.1240044

Sun, B., He, Z., Zhang, T., & Wang, R. (2016). Urban spatial structure and commute duration: An empirical study of China. *International Journal of Sustainable Transportation, 10*(7), 638–644. doi:10.1080/15568318.2015.1042175

Wolday, F. (2018). The effect of neighborhood and urban center structures on active travel in small cities. (Under review).

Wolday, F., Cao, J., & Næss, P. (2018). Examining factors that keep residents with high transit preference away from transit-rich zones and associated behavior outcomes. *Journal of Transport Geography, 66(*Supplement C), 224–234. doi:https://doi.org/10.1016/j.jtrangeo.2017.12.009

Wooldridge, J. M. (2014). Introduction to econometrics. United Kingdom: Cengage Learning EMEA.

Zegras, C. (2010). The built environment and motor vehicle ownership and use: Evidence from Santiago de Chile. *Urban Studies, 47*(8), 1793–1817.

Zhang, L., Hong, J. H., Nasri, A., & Shen, Q. (2012). How built environment affects travel behavior: A comparative analysis of the connections between land use and vehicle miles traveled in US cities. *Journal of Transport and Land Use, 5*(3), 40–52.

Zhou, B., & Kockelman, K. (2008). Self-selection in home choice: Use of treatment effects in evaluating relationship between built environment and travel behavior. *Transportation Research Record: Journal of the Transportation Research Board, (2077)*, 54–61.

The effect of neighbourhood and urban centre structures on active travel in small cities

Fitwi Wolday *(hamdwold@nmbu.no)*
Department of Urban and Regional Planning, Norwegian University of Life Sciences (NMBU)
P.O. Box 5003, N-1432 Ås, Norway
https://www.nmbu.no/en/faculty/landsam

Abstract

Densification is the key intervention strategy proposed in the urban sustainability planning literature. Nevertheless, the blueprint for action is still vague, and especially so in small cities. Is, for example, the premise for and reward of densification relatively transferable between city scales? In addition, does difference in centre structures and distribution of facilities in small cities have an implication for active travel? By focusing on three Norwegian small cities, this paper addresses how the built environment, travel attitude and differences in city-centre structure influence travel behaviour. Using descriptive statistics, ANOVA test and negative binomial regression on survey data, I find that attitude towards active travel as well as accessibility influence walk/bike trip frequencies significantly. Variation in small-city centre structure has also an important implication for active travel but the effect varies between facility types.

Keywords:

Built environment, travel attitude, city-centre structure, facility distribution

1. Introduction

This paper focuses on built environment factors influencing active travel in the context of small cities. The relationship between urban structure and travel behaviour has been one of the actively researched topics in urban planning during the last three decades. The focus, however, has mainly been limited to large cities, with very few exceptions (Hu, Xu, Shen, Shi, & Chen, 2018; Næss & Jensen, 2004; Sun, He, Zhang, & Wang, 2016). Even within the limited coverage of small cities, the size disparity among the cities labelled as small cities is immense. A small city in Chinese context, for example Changting (Hu et al., 2018), would qualify for a medium-to-large city in the European context.

Difference in urban size has important implications on whether and how the causal tendencies[1] (Bhaskar, 2008) between built environment and travel behaviour are manifested (Milakis, Cervero, & van Wee, 2015; Næss, 2015; Sun et al., 2016). As a result, knowledge derived from large cities may not be readily transferable to small city contexts. Density (say population density), for example, may be considered as proxy for local transit accessibility (Bhat & Guo, 2007). The assumption underlying such statements is, of course, that the city in question is large enough to support efficient and frequent transit service. Small cities lack the critical population base to promote an efficient and frequent public transport service. Therefore, high density is unlikely to manifest itself in higher transit ridership if the city size is small.

Scale (size) limitations constrain small cities from promoting a transit-oriented urban planning in mitigating private car use. Nonetheless, the inherent characteristics of being small do also make these cities ideally suited for active travel in reducing car travel and nurturing a healthy means of conveyance for local trips. Small cities are usually characterized (at least in Norway) by relatively compact (short distance between the centre and the fringe) and predominantly monocentric city configurations, which together create an urban environment that is reachable by non-motorized transport. Besides, commercial and personal services as well as institutional facilities are often concentrated at small-city centres. This in turn reduces the average distance from residential settlements to various facilities, making the city centre a potential destination that is accessible by active modes.

A sizable share of the Norwegian population live in small towns and hamlets, making this research a worthwhile undertaking. Data on settlement sizes for 2015 from Statistics Norway puts the

[1] The critical realist conception of causality that sees causal relationships as tendencies, which may or may not be observed depending on the alignments of different triggering factors (Bhaskar 2008). distinct from correlation

Norwegian population living in settlements[2] with population size of 30 000 or less at 44.3%. The proportion living in small cities with inhabitants ranging between 3 000 and 30 000 was about 28% of the total Norwegian population (Statistics Norway, 2015). Many of these small cities are car dependent with regional commuting patterns and high level of car dependency. Any serious effort on sustainable mobility can hence not yield the intended outcome without understanding the mobility dynamics of local travel in small cities.

Research in urban planning informs us that the extent of car use may be reduced by promoting a modal split that takes travellers away from cars and into transit and/or non-motorized modes. Urban planning measures designed to such ends include, among others, densification in and around city centres to contract the origin-destination gap, promoting transit oriented development and creating a conducive environment for walking/biking. The pertinent question here is then; can the compact development through densification in and around the city centre be a feasible planning strategy in a small city context?

This article aims to contribute in filling the knowledge gap by focusing on three Norwegian small cities with population size between 10 000 and 20 000 residents. Issues pertaining to the relationship between the built environment and active travel, and the role of travel attitudes in that relationship are investigated. Additionally, the effect on active travel when small-city centre structures deviate from monocentric pattern is probed.

The paper is organized in seven sections. The next section briefly presents the research objectives. The literature review in section three situates the stated objectives in the context of existing research. Section four takes up the conceptual framework followed by the data and method part in section five. Results and discussion is covered in section six followed by the concluding remark as the final section.

2. Research objectives

This article will address three interrelated issues. First, in light of the potential of active travel as a sustainable mobility means in small cities, the paper will try to identify important built environment attributes influencing non-work trip frequency to different destinations.

[2] Statistics Norway defines settlements as localities with continuous built up area with 200 or more inhabitants. The distance between the buildings shall normally not exceed 50 meters. Deviations are allowed when there are natural barriers such as rivers or arable land and land developments such as parks, sports facilities and industrial areas disrupting continuous development.

Second, the paper will explore travel attitude's direct and indirect effect (indirect effect via interaction with built environment-factors) on the extent of active travel. Social cognitive theory or ecological models attest that attitudes have significant influence on the decision whether to engage in active travel (Sallis, Owen, & Fisher, 2015). Whether an individual chooses to walk/bike as a mode of transportation when other options are available, depends on whether the person is motivated to walk/bike and the degree to which the built environment allows for it (Handy, 2015). Attitude influences the motivation to walk/bike which in return influences the distance or physical exertion one is willing to accept. Attitude alone is still not a sufficient condition for utilitarian active travel. The interaction between built environment and attitude (in addition to physical ability such as health) is what ultimately determines non-motorized travel behavioural outcome.

Third, investigate the effect of differences in city-centre structure[3] and the associated distribution of various facilities (destinations) on active travel. Development efforts in small cities may often take outward expansionary tendencies. For developers, land values may be expensive in city centres and redevelopment of an already developed land may be even costlier, leading to consolidation the expansionary pressures on low-density land-uses. Such expansionary land-use policies influence the land-use mix, which has an important implication for active travel. It can also influence the distribution of centre facilities and neighbourhood facilities in the urban space. This article will address the implications of city-scale structural differences and the resulting dispersion of facilities on active travel behaviour.

3. Literature review

The interest on travel by active modes is manifold. Non-motorized modes are easily accessible with little resource requirement, have negligible carbon footprint and are health-improving alternatives to motorized modes. Yet, the sustainability and health-improving potential of active travel is underutilized in many countries despite a significant proportion of daily trips being carried out over short distances. The 2013/14 national travel survey in Norway shows, for example, that 39 per cent of all trips are shorter than 3 kilometres (Hjorthol, Engebretsen, & Uteng, 2014). Considering the average walking and cycling distances of 2.2 and 5.5 kilometres respectively (ibid), many of these trips are within an acceptable walking/biking range.

There is generally large variation between countries in how active travel is utilized as a transport mode. Comparing European countries as a group against North America, about a tenth of all North

[3] City-center structure, as used in this paper, refers to the categorization of a small city as a single-centered or multiple-centered (polycentric). The corresponding term in larger metropolitan areas is metropolitan urban structure (Aguilera & Mignot, 2004; Næss et al., 2017).

American trips are made by active means, while the share of active travel is more than a quarter of all trips in the European countries (Susan Handy, Xing, & Buehler, 2010a; Pucher & Buehler, 2010). Intra-national differences within countries are also evident. In Norway, for example, according to the most recent travel survey from 2013/14, active travel accounts for 34 per cent of all trips in the largest four cities while the share is 26 per cent in the smaller cities[4] (Hjorthol et al., 2014).

The marked difference in active travel between countries and within different regions in a country complicates transferability of individual studies across geographic scales and jurisdictions. Many of these variations are likely the result of policy differences leading to different urban development trajectories, which again amplify and perpetuate the differences. European cities are characterized by denser and more dominant city centres with high land-use mixing and less urban sprawl compared to their North American counterparts (Susan Handy, Xing, & Buehler, 2010b; Næss, 2012; Pucher & Buehler, 2010). Active travel as a self-propelled transport mode is highly susceptible to distance, as long distances require greater physical exertion. Sprawling urban structures, with poor land-use mix and low density, require a level of physical exertion and exposure to the elements that is physiologically demanding. Within countries, even in countries with a high motivation for active travel, policy differences between municipalities can lead to sizable difference in active travel. Nielsen, Olafsson, Carstensen, and Skov-Petersen (2013), for example, found significant differences between Danish municipalities with strong cycling policies and those with less significant policies.

3.1. Travel-induced residential self-selection and active travel

Studies on the relationship between built environment characteristics and active travel are concerned with whether policies that alter the physical environment in favour of active travel stimulate more walking and biking. As a result, understanding the role of residential self-selection has been an important component of the causality puzzle between built environment and active travel. The body of knowledge from the last decade or so affirms that built environment influences active travel (Cao, Mokhtarian, & Handy, 2009a; Susan Handy, Cao, & Mokhtarian, 2006; Næss, 2006, 2014) even after accounting for residential self-selection. Yet, the estimated effect sizes of built environment variables on travel behaviour vary significantly between studies and travel induced residential self-selection is often the main go-to explanation, besides other reasons such as spatial scale, the appropriateness of empirical methods and data availability (Crane & Guo, 2012; Susan Handy, 2005; Mokhtarian & Cao, 2008).

People's travel attitude is often assumed to influence their residential choice resulting in what is known as travel induced residential self-selection that can potentially introduce bias in the built

[4] Small city in the report by Hjorthol et al. (2014) refer to city sizes of up to 50 000 residents.

environment estimates. Accounting for such possible bias, by controlling for travel attitudes, has therefore been a standard practice. For example, Cao (2010) concludes that not controlling for self-selection is likely to overstate utilitarian walking frequency by 64%. Such interpretations overlook the direct effect of attitude on active travel via motivating people to travel more and presumably longer. Besides, although attitudes do influence active travel (Cao, 2014), the influence may not necessarily or entirely be via residential choice (Næss, 2009, 2014).

There is growing evidence that travel attitudes, although relevant, are not at the top of the residential selection criteria (Cao, 2008; Filion, Bunting, & Warriner, 1999; Lindelöw, Svensson, Brundell-Freij, & Winslott Hiselius, 2017; Wolday, Cao, & Næss, 2018) and only marginally filter down to residential selection (Ettema & Nieuwenhuis, 2017). Moreover, it is also reasonable to believe that the opportunities the built environment presents to the use of non-motorized transport can affect the attitude of using such modes (Cao, 2014; Næss, 2014).

However, a marginal effect of travel-induced residential self-selection on active travel does not trivialize the role of travel attitudes in the propensity to travel by active means. Travel attitude is likely more important in explaining the variation in active travel than for car and transit travel (Cao, Mokhtarian, & Handy, 2009b), largely because of the physical exertion involved in active travel. Moreover, within similar urban structural contexts, people with positive attitude towards walking/biking tend to travel more by active means than those who have less preference for active travel (Susan Handy, 2005; Susan Handy et al., 2006). Hence, the direct effect of attitude on active travel is theoretically more appealing than the effect via travel induced residential selection.

3.2. Active travel and regional context

The extent of active travel varies considerably between work and non-work trips. As job commutes are often outside bikeable/walkable ranges, active travel rates are generally higher for non-work trips than for work trips (Boarnet & Crane, 2001; Cao et al., 2009a; Pucher & Buehler, 2010). In a small city setting where employment often tends to scatter over a wider regional area, the potential for active travel lies mainly on non-work trips. This is especially so for small cities that are within a regional sphere of influence of a bigger city. For non-work trips, walking and cycling is an important component of the local transportation system irrespective of regional context. In situations where a small city is a regional centre and employs a sizable share of the local work force, active travel can also be an important component of commuting modes.

Depending on a small city's regional context, this study adopts two categorizations of small cities: regional centres and satellites. The categorization is based on commuter flow patterns (Aguilera & Mignot, 2004; Engebretsen & Christiansen, 2011) and defines cities as regional centres if they employ at least 50 % of the resident workforce locally, while those with more than 50% out-commuting resident workforce are labelled as satellites.

3.3. Accessibility, city-centre structure and dispersion of facilities

Among the built environment factors, accessibility is often reported to be a strong if not the strongest indicator of walking/biking feasibility and hence the propensity for active travel (Susan Handy, 2005, 2015). This is not counter-intuitive. Many built environment factors such as intersection density, street pattern and block size are evaluated on how they affect distance as an impedance factor. Accessibility indicators on the other hand capture two important aspects of built environment characteristics: the ease of reaching the destination (impedance factor) and the attractiveness of the destination. Using survey data from eight neighbourhoods in Northern California, Susan Handy et al. (2006) found accessibility and particularly proximity to shops and services to be the most influential factor in increasing walking propensity.

Dalvi and Martin (1976) define accessibility as the ease with which any land-use activity can be reached from a location using a particular transport system. For slow modes such as walking and biking, 'ease' refers primarily to the distance between two points- the origin and destination. Defining accessibility in this manner does not differentiate between whether an accessibility measure is taken at the city centre or the periphery. Does it then matter to active travel behaviour, how different types of facilities are distributed in the city space– whether they are concentrated in the city centre, scattered throughout or clustered in multi-centred city structure?

Two identical facilities with equally high score in accessibility index may trigger different travel responses depending on the type of facility and their respective location in the urban space. Travel decisions are influenced largely by accessibility to concentration of facilities than accessibility to a single facility within a category (Næss, 2006). However, agglomeration synergies generated from concentration of facilities may vary between facilities. Facilities such as grocery stores that are less diversified and that are frequently visited by customers may gain less from agglomeration in central locations. From the travel demand side, non-motorized transport, as a slow mode, is especially susceptible to time constraint and effort. Decision to travel by active means is therefore influenced also by how frequently a trip has to be made and the flexibility in rescheduling that trip (Vilhelmson, 1999; Ås, 1978).

Specialized facilities and occasionally visited facilities need a large catchment area of potential customers (Christaller, 1966). Owners of specialized facilities are therefore better off choosing a location that maximizes average access, which, in a monocentric city structure often is the centre of the city. Conversely, for facilities such as grocery stores, elementary schools, day care etc. where the ‘customer base’ can narrowly be defined at a neighbourhood scale, concentration at city centres may not be the optimum location choice. Instead, a dispersed location closer to residential neighbourhoods may be a more viable option.

As small cities grow and expand outward, understanding the dynamics of location choice has practical planning implications on land-use pattern. In this paper, the analysis involving distribution of facilities is organized by facility groups to reflect the optimal locational choice of different facilities. A disaggregate accessibility measure for each facility group has the advantage of enabling an assessment of the relative importance of specific characteristics of the built environment in explaining active travel (Susan Handy, 2005).

4. Conceptual framework

Unlike motorized travel that, to large extent, can be categorized as a derived demand, recreational walking/biking is an important and significant proportion of the overall travel by active modes. Since the interest of this paper is sustainable transport, the focus is limited to utilitarian active travel. Unlike driving, a walking trip for grocery shopping or a stroll to a café is still not entirely a derived demand. An individual who chooses to walk to a grocery store may want to combine the grocery shopping with walking as an exercise. In such cases the walking, the process of getting to the destination, would have an intrinsic value (Cao, Mokhtarian, & Handy, 2008; Susan Handy, 1996; Mokhtarian & Salomon, 2001; Ory & Mokhtarian, 2005) making active travel even more appealing.

One of the main objectives of research on active travel is to understand people’s tendency to travel by active means when other options are available. The two main factors influencing individual’s choice to travel by active modes are the motivation to walk/bike and the degree to which the physical environment facilitates or curtails it (Susan Handy, 2010, 2015). A finding by Cao et al. (2009b) further affirms that not only are both built environment and travel attitudes (which feed into the motivation to travel actively) significantly linked to active travel magnitudes but also explain comparatively more of the variation in non-motorized travel than for auto and transit travel.

This paper builds on Handy’s (2015) conceptual model[5] on active travel, with a few adaptations. Two of the main adaptations to Handy’s model are that attitudes/preferences are presented separately from personal characteristics and community design is replaced by built environment at different geographic scales.

Studies on active travel almost exclusively focus on neighbourhood scale variables due to the limited spatial reach of active modes. In a small city’s context, city scale built environment factors (such as

[5] Readers are advised to consult Handy (2015) for an elaborate explanation of the conceptual framework.

city-centre structure and residential distance from the city centre) are also expected to influence active travel by influencing proximity to concentrations of facilities. Figure 1 illustrates the various factors influencing active travel.

Built environment at different scales (neighbourhood and city scale) influences the proximity to various facilities laying out the conditions for the feasibility of active travel as a transport mode. Different facilities have different criteria for location selection (as presented in section 3.3). For some facilities, neighbourhood location may be an optimal location while others may tend to locate in congregation with other facilities (which often but not always is at the centre of small cities) to increase market access and draw on agglomeration effects. Accordingly, the effect of built environment on the feasibility of active travel is expected to differ depending on how different facilities are distributed in the urban space. For example, building a shopping centre at the fringe of the city centre may attract some of the centre facilities, which will in turn increase the average walking distance and reduce active travel to these facilities.

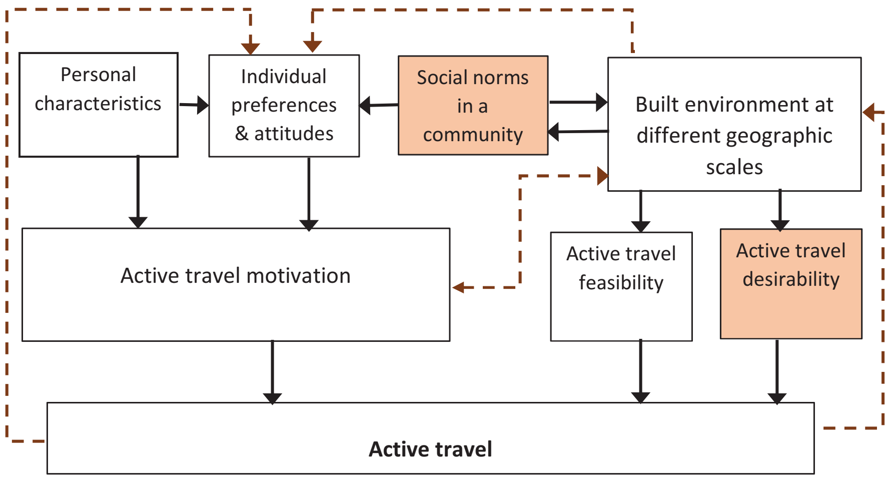


Figure 1. Conceptual model of active travel. Adapted from Susan Handy (2015).
Note: Broken lines and light brown boxes indicate causal pathways and variables not considered in this paper.

Motivation occupies centre stage in the decision to travel by active mode due to the physical exertion involved and especially so in small cities where driving is the dominant mode. The motivation for active travel depends on personal factors such as ability (physiological characteristics, age) and individual preferences and attitudes (confidence, preferences, habits and perceptions) (figure 1). The motivation to walk/bike is also influenced by social norms. The attitude towards and the practice of traveling by active means in a community influences individual choice to walk/bike. If walking/biking is seen as a dominant mode of transport, individuals may likely adopt the dominant behaviour.

However, the likelihood that a walk/bike mode is viewed as a dominant or normal mode of transport is not independent of urban structure. For those who are motivated, the physical environment (both the built and natural environment) influences active travel through its influence on the feasibility and desirability of biking/walking. The location of facilities and the street configuration connecting the various facilities determine whether active travel is a feasible mode. The aesthetic qualities along the way and at destinations influence the desirability of the trip by an active mode by raising the autotelic (intrinsic) value of the trip (Mokhtarian & Salomon, 2001; Ory & Mokhtarian, 2005; Stefansdottir, 2014).

4.1 Travel attitude and residential self-selection

Attitude is expected to influence the likelihood of whether at all to travel by active means and the magnitude of active travel. Motivation works in tandem with the physical environment to create the sufficient condition. Without motivation, choosing active mode is less likely unless that is the only mobility option. And without the conducive physical environment for walking/biking there would be no active travel due to safety concerns and physiological limits (Susan Handy, 2015).

In such circumstances, treating travel attitudes as a source of bias (due to travel induced residential self-selection) leads to more bias than corrects for it. Therefore, the theoretical argument for travel induced residential self-selection bias in the case of active travel appears more of a tempest in a teapot (Næss, 2014).

In this paper, attitude is included in the model not to control bias due to residential self-selection but rather as a variable of prime interest due to its direct effect of active travel both independently and possibly through its interaction with the built environment. An interaction term between accessibility and attitude is included to assess whether the effect of accessibility also varies by the degree of active travel liking. Empirical models that specify travel attitude without addressing a plausible interaction between built environment and attitude would under- or overstate the effect of built environment on active travel depending on the sign of the interaction term.

Figure 2 below presents an outlook of how residents' attitudes towards active travel are distributed in the three case cities. The histogram shows the relative share of residents with low and high positive attitudes towards active travel at different distance rings around the city centre. It is apparent from figure 2 that attitude towards walking/biking is fairly high throughout the urban region.

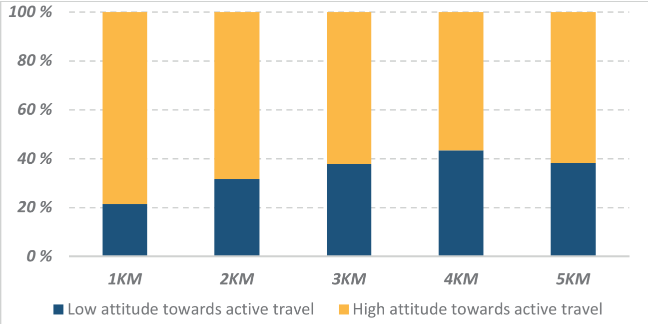


Figure 2. Residents' attitudes towards walking/biking at different distance rings from the city centre

5. Data and method

The study area comprises of three small cities in the south-eastern part of Norway: Kongsvinger, Jessheim and Drøbak with population size in their continuous built-up area ranging between 11 000 and 17 000 (figure 3 & table 1). The survey sampling frame encompasses all residential units in the continuous built-up area of the three cities. A respondent between the age of 18 and 75 was randomly selected from the adults in each residential unit resulting in a sample of 4591, 5609, and 5074 units from Kongsvinger, Jessheim and Drøbak respectively.

Table 1. Aggregate description of survey area

Settlement areas (cities)	Number of residents	Area (km^2)	Density (residents/km^2)	Share of municipal population
Drøbak	13405	5.52	2428.4	86 %
Jessheim	16595	6.84	2426.2	51 %
Kongsvinger	11969	7.87	1520.8	67 %

Source: (Statistics Norway, 2015)

The survey was conducted using a self-administered web-questionnaire. An invitation letter was sent to each potential respondent in December 2015 with information on the purpose of the survey, how to access and complete the survey and contact information. To incentivize participation, respondents who completed the survey were eligible for a gift card lottery worth 6 000 NOK (approx. USD 750).

The three cities also differ in the way the city centres are structured. Drøbak has two competing centers. The city market (Torget) close to the harbour is traditionaly considered as the main city center. The second center, AMFI-Drøbak, is a recent development with shopping and other service-rendering facilities at the outskirt of the city. Jessheim and Kongsvinger, on the other hand, have monocentric urban structures with most of the commercial and other service facilities concentrated in the city centre.

The net sample reflects the population characteristics well with minimum skewness, as reported in table 2 below. Sample demographic characteristics such as household size, average number of children per household, average number of dependents 17 years of age and below, average respondent's age, and gender proportions conform well to their population counterparts in all three cities. On the socio-economic factors, respondents with college education or above seem to be overrepresented. However, the disparity is likely lower than what appears in table 2 as the values are computed slightly differently between the sample and the population[6].

[6] The proportion of respondents with college education in the sample shows the share of college educated individuals in the age bracket of 18 to 75 years. For the municipalities, it is calculated for the population subgroup 16 years or older. Besides, a higher proportion of individuals with college education live in the cities, raising the city average compared to the municipality average. Average household income is also slightly skewed towards higher income individuals. However, the difference between the sample and population average is likely to be lower than reported above due to the above two reasons. Share of the labor force participants in the sample mirrors the population average well.

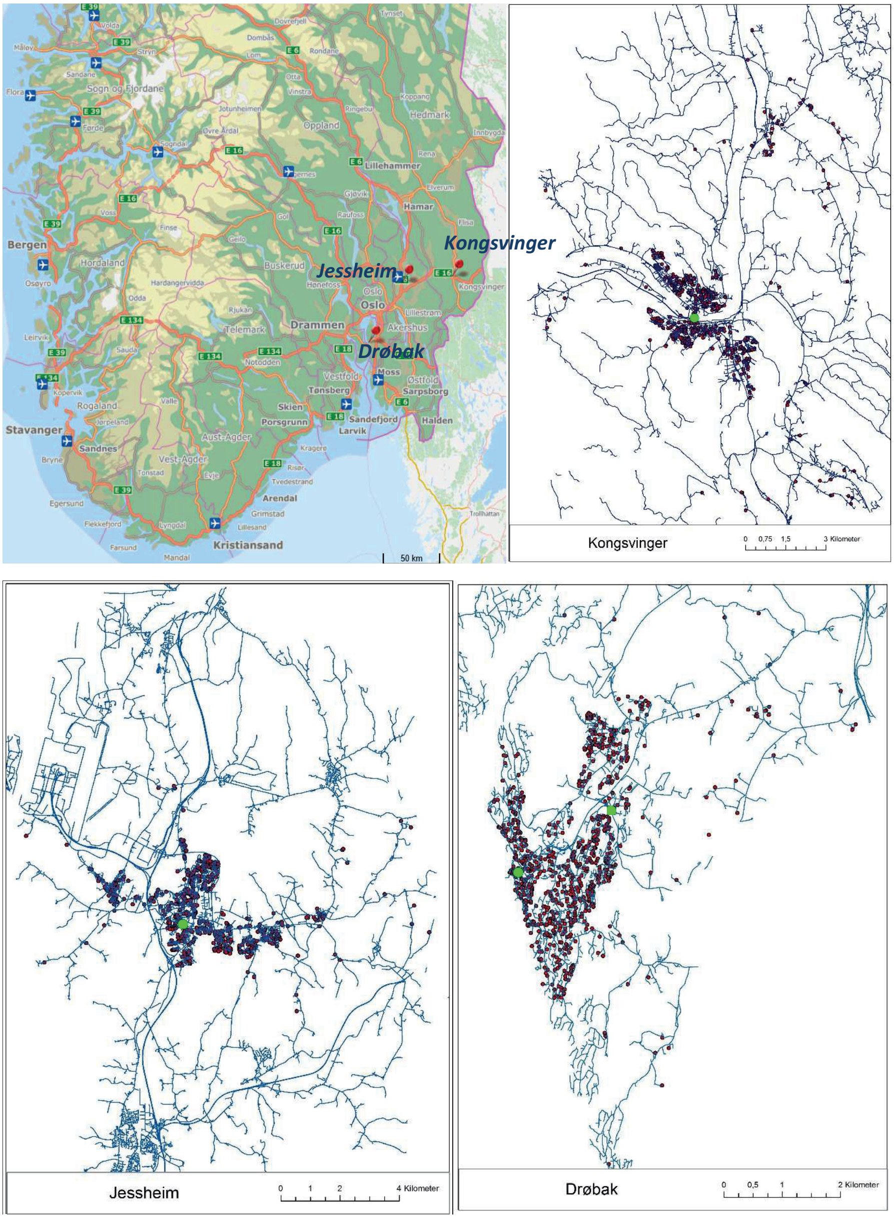


Figure 3. Map of southern part of Norway and street network map of the case cities. The green dots represent city centres and the red dots represent residential units in the sample.

Table 2. Comparison of key indicators between survey data and the population from which it was drawn.

	Kongsvinger (N=507)	**Municipality of Kongsvinger**	**Jessheim (N=616)**	**Municipality of Ullensaker (includes Jessheim)**	**Drøbak (N=843)**	**Municipality of Frogn (Includes Drøbak)**
Average household size	2.13	2.05	2.51	2.34	2.50	2.27
Average number of children per household	0.46	0.40	0.65	0.59	0.60	0.51
Proportion of children aged 0-17	22.0 %	18.9 %	25.8 %	24.8 %	24.2 %	22.0 %
Average respondent age (18<=age<=75yrs)*	52.0	47.3	48.7	43.7	52.0	47.0
Gender (Share of female)*	46.8 %	51.3 %	51.0 %	49.4 %	53.3 %	51.4 %
Education level (Share of college level education)	54.2 %	21.6 %	59.2 %	25.9 %	66.5 %	35.0 %
Proportion employed	66.3 %	56.7 %	74.5 %	68.8 %	72.2 %	66.8 %
Average household income (1000 NOK)	756	508	854	571	893	583

**Gender (Proportion of female) is calculated for the sampling frame, i.e. section of the population>=18 years old*

The survey included indicators for attitude towards walking/biking as well as topography. Attitude towards walking/biking was measured by asking respondents to indicate whether they agree or disagree with the statement "I prefer to walk/bike instead of driving whenever possible" in a five-point scale ranging from disagree completely '1' to agree completely '5'. Similarly, topography was also measured using a five-point scale. Respondents were asked to indicate whether they agree or disagree with the statement 'the streets in my neighbourhood are hilly, which makes it difficult to bike". Both variables enter the model as continuous variables.

The survey data were supplemented with GIS-generated spatial data such as distance to various facilities and residential distance to the city centre. Based on distance to facilities, a disaggregate accessibility index was computed for all residential homes. The accessible range by active modes around residence i, is defined as an area within 805 meter (half-mile) radius of the residence as the crow flies. In order to accommodate the distance decay factor while at the same time accounting for attractiveness, the accessibility index was computed using a gravity model based on Hansen's (1959) and Harris' (2001) work as follows:

$$A_{ij} = \sum_j W_{ij}\, e^{-C_{ij}}$$

The accessibility indicator A_{ij} measures the accessibility of facility type *j* from residence i within an accessible range by an active mode. W_{ij} represents the number of type j facilities at a half-mile distance from residence i. The impedance factor, distance along the road network between residence i and facility *j* is represented by $e^{-C_{ij}}$, where higher values of C_{ij} represent less access. The accessibility index A_{ij} is computed for facilities including grocery stores, facilities for errands other than grocery, restaurants/cafés, medical services (medical/dental clinic) as well as fitness facilities.

To account for the possibility that the effect of accessibility on active travel could vary between facility types, I categorized walk/bike trips into two groups depending on the frequency with which an activity is carried out on the one hand and the degree of specialization of the facility on the other. Frequency of an activity has an implication on time constraint, which is critical for travel by active modes whereas degree of specialization has an implication for the centre-periphery location choice. Accordingly, grocery stores, which have high activity frequency and low level of specialization, are constituted as one facility group, **neighbourhood facility**. Other facilities that are not visited as often and have some level of specialization (other errands, cafés and restaurants and medical clinics) are grouped together as **centre facilities** in the succeeding analysis. In accordance with this grouping, the accessibility indices for the individual facilities are aggregated across facilities to generate average group accessibility indices.

Another neighbourhood-scale built environment linked to accessibility is street network connectivity. Street network connectivity is an important characteristic with significant influences on active travel (Marshall, Norman, & Stephen, 2015). In this paper, street network connectivity is represented by intersection density and is measured as the number of intersections per unit area. The unit area is defined as a circular area around a residence with a half-mile (805 meters) radius. The calculation is performed using network analysis in ArcMap.

In addition to accessibility index and street connectivity, population density, residential distance from the city centre and a measure of facility dispersion (distribution) are included as additional built environment attributes. Apart from built environment variables, the analysis includes socio-economic attributes (income, education), demographics (age, number of children, household size) and attitudinal variable. Residential terrain variable indicating the suitability of the topography around the residence for active travel (e.g. hilly slope) and car availability[7] are also included.

Based on the accessibility index, attitude towards active travel and the measure of facility dispersion, I computed two interaction terms. The first interactions term is computed as the product of attitude and accessibility and represents the interaction between built environment and attitude. The essence of including this interaction term is to test whether the effect of accessibility on active travel trips partially depends on individual attitude towards active travel. With attitude and accessibility having the expected signs, a significant interaction term with a negative sign would mean that difference in attitude is more important in areas of low accessibility, and its importance diminishes as accessibility increases.

The second interaction term introduces an interaction between accessibility and the measure of dispersion to account for whether the effect of accessibility on active travel varies depending on how facilities are distributed. Residential distance from the city centre is used as a measure of how concentrated or dispersed the facilities are vis-a-vis the city centre. Since accessibility is measured as facilities accessible within a half-mile radius of the residence, residential distance from the city centre can approximate the average distance of accessible facilities associated with each residential unit from the city centre.

[7] Controlling for car availability in this paper is not intended to mean that car access has to be controlled for due to its influence on residential choice. In fact, car ownership is more a result of the built environment than the other way around (Næss, 2009). In addition, the study here is not about travel distance by car but rather about trip frequency by active means. Therefore, controlling for car access is deemed necessary since the intention is to analyze the effect of built environment variables on walk/bike trip frequencies when other mobility alternatives are available.

The outcome variable, the number of walk/bike trips to non-work destinations, is a count variable and hence a negative binomial regression[8] is adopted as the appropriate model. The negative binomial regression models are estimated recursively by including one group of independent variables at a time. Variables that are insignificant at a 10% significance level are dropped at each step. In the final stage, parsimonious models with estimates that are significant at a 5% level are reported.

6. Results and discussion

6.1 Which factors increase the propensity for non-work trips by active modes?

In accordance with the outline in section two above, I begin the analysis by investigating the effect of built environment on non-work trip frequency. The dependent variable is weekly trip frequency to non-work destinations. The independent variables included are neighbourhood built environment factors (population density, accessibility index, and intersection density), demographics (household size, gender, age mean centred), socio-economics (education, income and employment), topography and a car-access dummy. Besides, residential distance from the city centre is included as an independent variable for the city-scale analysis.

Results from the negative binomial regression (table 3) show that, at the neighbourhood scale, two built environment factors (intersection density and accessibility to facilities) and attitude towards walking/biking increase the likelihood of walking/biking. I also tested for the interaction between Accessibility and attitude to see if the effect of accessibility depends on attitude. The interaction term turned out to be insignificant and Akaike Information Criterion (AIC), the statistic for model selection, show that it adds no improvement to the specified model. This is not surprising for two reasons: first, accessibility is defined for a half-mile distance, which is tolerable for walking but a little short for biking. Second, the active travel variable measures biking and walking trips jointly.

Employment, access to car and topography[9] reduce the likelihood of walking/biking as expected. The elasticity estimates show that attitude is the strongest influence on the propensity to travel by active means when other alternative means of travel is available. This can have an important policy implication on how to change individual and community level perceptions and norms towards active travel, for example, through awareness campaigns. Awareness campaigns are found to significantly influence physical activity (Barnes et al., 2013).

[8] A chi-square test of dispersion was used as a criterion to choose between Poisson and Negative Binomial Regression Models. A comparison between the expected count and observed counts, given the mean count, also lead to the same conclusion.
[9] Topography refers to the difficulty of biking due to hilly streets in the neighborhood.

Table 3. Negative binomial regression estimates of active travel covariates

	Coefficient	P-value	Elasticity
Intersection density	.00129	0.000	.34607
Walk/Bike attitude	.27762	0.000	.95739
Accessibility to facilities	.00797	0.000	.06662
Employment	-.32212	0.000	-.23076
Car access	-.63743	0.000	-.61260
Topography	-.05907	0.002	-.13600
Constant	1.66543	0.000	
Nagelkerke R^2		*0.224*	
N		*1643*	

Note: The parameters of the negative binomial regression are estimated with robust standard errors
Accessibility to facilities is the cumulative accessibility index across individual accessibility indices for grocery stores, restaurants/cafés, medical facilities and fitness facilities.

Active travel is a local medium of transport. Neighbourhood scale is thus often considered as the appropriate geographic scale for studies on active travel behaviour. However, the influence of the city centre is present in many neighborhoods as the edge of the small cities is within 3-6 kilometres from the city centre. Residential distance from the city centre is therefore introduced to investigate how neighbourhood variables are affected when a city scale variable is included into the model. Since the three cities vary in their centre structures, a separate model is run for each city. *Negative binomial regression* estimates that are significant in either of the cities are reported for all of them to assist inter-city comparisons. Results are reported in table 4.

Table 4. Neighbourhood- and city scale built environment effects on active travel behaviour

	Kongsvinger		Jessheim		Drøbak	
	Coefficient	**Elasticity**	**Coefficient**	**Elasticity**	**Coefficient**	**Elasticity**
Residential distance from city centre	-.2979 (0.002)	-.4903	-.3463 (0.000)	-.7148	-.0480 (0.301)	-.0907
Walk/Bike attitude	.3273 (0.000)	1.1820	.2292 (0.000)	.7956	.2470 (0.000)	.8294
Accessibility to facilities	.0022 (0.616)	.0138	.0016 (0.299)	.0161	.0146 (0.000)	.1244
Employment	-.4585 (0.000)	-.3015	-.2286 (0.016)	-.1721	-.3332 (0.000)	-.2396
Car access	-.5506 (0.006)	-.5294	-.5562 (0.000)	-.5370	-.6561 (0.000)	-.6292
Topography	-.1191 (0.006)	-.2928	.0208 (0.707)	.0291	-.0640 (0.028)	-.1852
Constant	2.5254 (0.000)		2.7114		2.1429 (0.000)	
Nagelkerke R^2	*0.287*		*0.290*		*0.189*	
N	*365*		*522*		*733*	

Note: P-values in parenthesis

Intersection density is dropped from the model because it is highly correlated with residential distance from the city centre in all three models. Its inclusion in the model makes residential distance from the city centre insignificant in Kongsvinger. Residential distance from the city centre has the expected sign in all three cities but the effect is insignificant in Drøbak. In both Kongsvinger and Jessheim, active travel propensities are higher the closer one's residence is to the city centre but the magnitude of influences is stronger in Jessheim than in Kongsvinger.

A two-sample t-test confirms that the influence of residential distance from the city centre in Jessheim is stronger than that of Kongsvinger. These results are as expected given the divergence in city centre structures and difference in concentration of facilities at the city centre. Jessheim has a denser city centre with higher concentrations of facilities relative to the other two cities.

When the city scale variable was introduced in to the model (table 4), the accessibility variable turned out to be insignificant in the cities with monocentric centre structure whereas it remains significant in Drøbak where the centre is more diffused.

6.2 How does the distribution of facilities in the urban space matter for active travel?

Lumping up different facilities under one active travel variable, as in tables 3 and 4, depicts the general trend of the covariates. However, such an aggregate method may lose certain important nuances, as the effect of accessibility is likely to vary between facility types. To capture a more nuanced effect of accessibility on active travel, the facility types are categorized into two groups: neighborhood facilities (grocery stores) and centre facilities (facilities for errands other than grocery stores, cafés and restaurants and medical clinics). Figures 4 and 5 depict the distribution of grocery stores and centre facilities in each of the three cities, which also reflects the contrast in city centre structure among the cities.

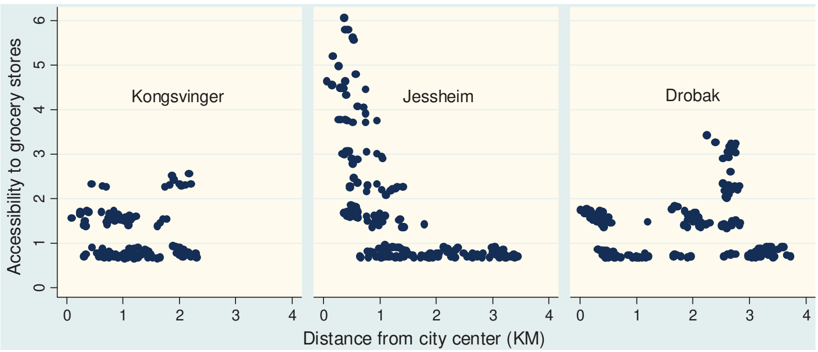
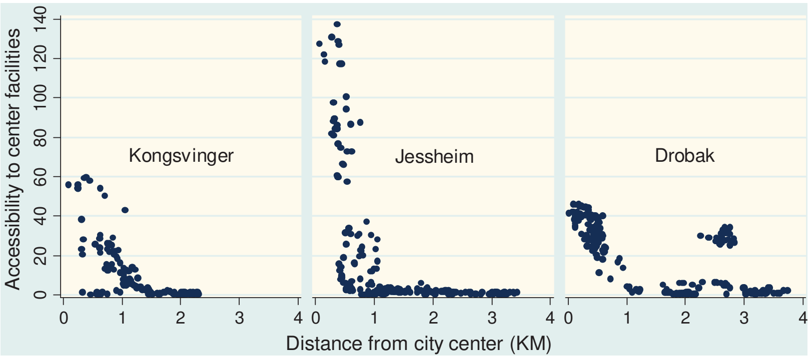


Figure 4. Distribution of accessible grocery stores at different distances from the city centre.

Kongsvinger has a fairly homogeneous distribution of grocery stores within a two kilometre radius of the city centre while Drøbak has a higher concentration of grocery stores at the fringe of the city. Jessheim differs significantly in that a very substantial proportion of grocery stores are concentrated at the city centre.

The distributional pattern for the centre facilities (Other errands, medical facilities and restaurants/cafés) is denser around the city centres but the contrast between the cities is of a similar trend to that of grocery stores. The distribution of centre facilities is densest within one-kilometre radius of the city centre in Jessheim and Kongsvinger, although the density is higher in Jessheim. In the case of Drøbak, however, centre facilities are clustered between two locations: one at the city centre and the other at a shopping centre in the outskirt of the city.

Figure 5. Distribution of accessible centre facilities at different distances from the city centre.



The question then is: does difference in city centre structure and the ensuing pattern of dispersal of facilities influence the propensity to travel by active modes? Moreover, does that influence differ by facility type? To answer these questions, I begin by an analysis of variance (ANOVA) with Bonferroni post hoc test for the three cities. Results are shown in table 5. Both the ANOVA results and the results from negative binomial regression are for the sub-sample where accessibility is greater than zero[10].

[10] The accessibility to facilities associated with a give residential unit is calculated for a half-mile radius around the residence. Some residential units do score zero in the accessibility index and the sub-sample in this section of the analysis includes only those houses with positive values in the accessibility index.

Table 5. Comparison of trip frequency between city-pairs by facility group.

Difference between cities	Travel behaviour	
	Comparison of trip frequency to grocery stores	**Comparison of trip frequency to centre facilities**
Jessheim - Kongsvinger	0.153 (1.000)	0.808 (0.120)
Drøbak – Kongsvinger	-1.091 (0.004)	-0.416 (0.774)
Drøbak – Jessheim	-1.243 (0.000)	-1.224 (0.001)

Note: Trip frequency is measured as number of trips in a typical month during the fall. Significance level (p-values) shown in parenthesis.

The ANOVA test shows that Jessheim and Kongsvinger have higher rates of active travel to grocery stores compared to the city of Drøbak. Drøbak and Kongsvinger appear to have a relatively similar distribution in grocery stores but residents in Kongsvinger walk/bike more to these destinations than those in Drøbak. This is likely because some of the main grocery stores are clustered at the shopping centre at the fringe of the city of Drøbak (see fig.3). In Kongsvinger the grocery stores are distributed throughout the urban space, which makes them more accessible. Regarding trips to centre facilities, residents in Jessheim undertake significantly more trips by bike and/or on foot compared to their counterparts in Drøbak. Moreover, Jessheim has higher walk/bike rates than Kongsvinger, and Kongsvinger on its part has higher walk/bike rates to centre facilities than Drøbak but the differences are statistically insignificant in both cases.

To investigate the existence of systematic relationship between the distribution of facilities and active travel behaviour, a negative binomial regression of trip frequencies was modelled for each facility group: one for grocery stores and the other for centre facilities. The independent variables in the models comprise of a measure of facility dispersion (average distance of facilities from the city centre), built environment factors, demographics, socio-economics, attitudinal factors and the interaction term between accessibility and the measure of facility dispersion. Variables that are significant at a 5 percent significance level in either of the two models are retained to facilitate comparison.

Dispersion of grocery stores has a positive sign, meaning that a decentralized location of grocery stores increases the likelihood of active travel. At the same time, we see that the interaction term between accessibility and dispersion is negative but the independent effect of dispersion is higher than that of the interaction term, which makes the overall effect of dispersion on trips to grocery stores positive. The negative estimate for the interaction term stipulates that high accessibility associated with higher degree of dispersion of facilities leads to lower propensity of travel by active means. Higher accessibility with higher dispersion can be achieved, for example, due to higher concentration of grocery facilities in shopping centres at the outskirts of a city.

Table 6[11]. The effect of spatial distribution of facilities on active travel

	Walk/bike trips to grocery stores			**Walk/bike trips to centre facilities**		
	Coefficient	**P-value**	**Elasticity**	**Coefficient**	**P-value**	**Elasticity**
Dispersion of facilities*	.1551	0.009	.2360	-.3265	0.000	-.6393
Accessibility**	.2031	0.000	.2933	.0012	*Not sig.*	.0103
Interaction: dispersion and accessibility#	-.1002	0.015	-.1871	.0077	0.020	.0589
Walk/Bike attitude	.2644	0.000	.9614	.2240	0.000	.7732
Employment	-.1831	0.018	-.1270	-.2891	0.000	-.2052
Car access	-.4313	0.000	-.4080	-.5404	0.001	-.5179
Topography	-.0454	*Not sig.*	-.0980	-.0900	0.000	-.2100
Constant	1.1655	0.000		2.0874	0.000	
Nagelkerke R^2		*0.159*			*0.270*	
N		*613*			*1510*	

Note: The parameters of the negative binomial regression are estimated with robust standard errors
* Measures the average distance of facilities from the city centre for each of the two facility categories.
** A gravity based measure of accessibility as described above. Accessibility indicator for the centre facilities is the sum of accessibility for the three centre facility groups.
\# Refers to the interaction term, i.e. a product of accessibility and the measure of dispersion.

From the remaining built environment attributes specified in the grocery model, the accessibility index has the strongest positive influence on trip frequency to grocery stores and corresponds with previous findings (Ewing & Cervero, 2010). Although the interaction term is negative and somewhat reduces the independent effect of neighbourhood-scale accessibility, the cumulative effect still remains positive.

For centre facilities, centralization is by far more important than the neighbourhood accessibility in increasing walk/bike trips. Decentralization away from the city centre reduces the likelihood of non-motorized trips to centre facilities by a significant extent while the accessibility index is insignificantly associated with trip frequency to centre facilities. The interaction term between the accessibility index and dispersion of centre facilities is statistically significant, although its effect size is small. This reveals that when dispersion boosts neighbourhood-scale accessibility, it may marginally increase the propensity to walk/bike to centre facilities.

Consistent with the findings in tables 3 and 4, attitude has by far the strongest influence on the propensity to walk/bike in both models. Besides, access to car, employment and topography all reduce walking/biking trips in both models, but topography is insignificantly associated with trips to grocery stores.

[11]The independent variables specified in the model include residential distance from the city center, population density, intersection density, accessibility index, attitude toward walking/biking, gender, age, presence of children in the household, employment, education level, household size, income and topography. Intersection density is dropped from the 'grocery model' due to high correlation with the measure of dispersion and accessibility.

6.3 **Limitations**

This study has a couple of limitations. The data utilized in this paper treats active travel as one mode. The dependent variable is defined as the number of walking/biking trips in a typical week during the fall. The trips are denominated by trip purposes. Lumping up biking and walking together and treating them as though they are a single mode may lead to a limitation known as unidentified geographic context problem or in short UGCoP (Kwan, 2012; Kwan & Weber, 2008) . UGCoP refers to an empirical problem or a bias associated with arbitrarily identifying the effective zones of a travel mode. Since walking and biking have different effective zones (Nielsen et al., 2013), combining both modes into one may miss certain nuances as to which built environment variables are effective in promoting either mode.

On the bright side, the neighbourhood characteristics that influence both modes are largely similar. Moreover, the number of walking trips greatly surpasses biking trips. The Norwegian average for smaller cities shows that walking accounts for about 81 per cent of active travel trips according the recent National Travel Survey from 2013/2014. Given that the aim of this paper is to identify influential built environment attributes on active travel in a multivariate regression setting, I maintain that combining both biking and walking will not be a major source of bias.

Another limitation relates to delimiting a half-mile accessibility range, which is more appropriate for walking than for cycling. Moreover, pedestrian and cyclist shortcuts and paths are not included as routes. I believe, however, this later limitation will not have significant bias, as the block sizes in the three investigated small cities are generally small with human-scale proportions between intersections.

Lastly, a respondent’s attitude towards active travel is measured based on a five-point Likert item where respondents indicated whether they agree or disagree with the statement “I prefer to walk/bike instead of driving whenever possible”. Ideally, travel attitudes are best represented using a battery of Likert items measuring different attitudinal aspects around the behavior studied (in this case travel by non-motorized modes).

7. Conclusion

This article set out with three research objectives: First, to identify built environment characteristics with significant influences on active travel. Second, to explore the role of travel attitudes as well as the interaction between attitudes and built environment in influencing travel behaviour by active modes. Third, to explore the implication of variations in city centre structures and the resulting distribution of facilities on active travel. Survey data from three Norwegian small cities were used to address the research objectives.

The analysis finds attitude towards active travel to exert strong influence on the propensity to bike/walk. When other means of travel are available, the decision to commit oneself to walk or bike depends, largely, on the motivation to do so. Neighbourhood-scale accessibility is also important but its influence varies by trip purpose (facility type). For trips to grocery stores, neighbourhood accessibility is highly influential whereas for centre facilities centralization (concentration of facilities at the city centre) is more strongly associated with walk/bike frequency. Topography (e.g. hilly neighbourhoods) also reduces the likelihood of traveling by active modes irrespective of destination type.

This research clearly demonstrates that facility distribution has significant effect on the propensity to use active modes. Two policy implications can be drawn from this. First, planners should avoid measures that lead to sprawling of centre facilities, for example, commercial land-uses such shopping centres at city fringes. Second, since grocery stores accessible at a neighbourhood scale increase the propensity of active travel, planners should reflect on new residential developments in such a way that these developments support neighbourhood facilities such as grocery stores.

The analysis also reveals that attitude towards active travel exerts strong influence on people's tendency to travel by non-motorized modes. Therefore, awareness campaigns to sway individual and community attitudes coupled, for example, with incentives to the adoption of electric bikes in order to reduce the level of exertion associated with topographical contours may likely boost walk/bike frequency.

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References

Aguilera, A., & Mignot, D. (2004). Urban Sprawl, polycentrism and commuting. A comparison of Seven French Urban Areas. *1*, 93-113.

Barnes, R., Giles-Corti, B., Bauman, A., Rosenberg, M., Bull, F., & Leavy, J. (2013). Does neighbourhood walkability moderate the effects of mass media communication strategies to promote regular physical activity? *Annals of Behavioral Medicine, 45*(1), 86-94.

Bhaskar, R. (2008). *A realist theory of science*. London ; New York: Routledge.

Bhat, C. R., & Guo, J. Y. (2007). A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. *Transportation Research Part B, 41*(5), 506-526. doi:10.1016/j.trb.2005.12.005

Boarnet, M., & Crane, R. (2001). *Travel by design: the influence of urban form on travel*. Oxford: Oxford University Press.

Cao, X. (2008). Is Alternative Development Undersupplied? Examination of Residential Preferences and Choices of Northern California Movers. *Transportation Research Record: Journal of the Transportation Research Board, 2077*, 97-105. doi:10.3141/2077-13

Cao, X. (2010). Exploring Causal Effects of Neighborhood Type on Walking Behavior Using Stratification on the Propensity Score. *Environment and Planning A, 42*(2), 487-504. doi:10.1068/a4269

Cao, X. (2014). Examining the impacts of neighborhood design and residential self-selection on active travel: a methodological assessment. *Urban Geography*, 1-20. doi:10.1080/02723638.2014.956420

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2008). No Particular Place to Go: An Empirical Analysis of Travel for the Sake of Travel. *Environment and Behavior, 41*(2), 233-257. doi:10.1177/0013916507310318

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009a). Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Empirical Findings. *Transport Reviews, 29*(3), 359-395. doi:10.1080/01441640802539195

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009b). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A, 43*(5), 548-559. doi:10.1016/j.tra.2009.02.001

Christaller, W. (1966). *Central places in southern Germany*. Englewood Cliffs, N.J.: Prentice-Hall.

Crane, R., & Guo, Z. (2012). Toward a Second Generation of Land-Use/Travel Models: Theoretical and Empirical Frontiers. In N. Brooks, K. Donaghy, & G. Knaap (Eds.), *The Oxford handbook of urban economics and planning* (pp. 522-544). Oxford: Oxford University Press.

Dalvi, M., & Martin, K. (1976). The measurement of accessibility: Some preliminary results. *Transportation, 5*(1), 17-42. doi:10.1007/BF00165245

Engebretsen, Ø., & Christiansen, P. (2011). *Bystruktur og transport: en studie av personreiser i byer og tettsteder*.

Ettema, D., & Nieuwenhuis, R. (2017). Residential self-selection and travel behaviour: What are the effects of attitudes, reasons for location choice and the built environment? *Journal of Transport Geography, 59*, 146-155. doi:10.1016/j.jtrangeo.2017.01.009

Ewing, R., & Cervero, R. (2010). Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association, 76*(3), 265-294. doi:10.1080/01944361003766766

Filion, P., Bunting, T., & Warriner, K. (1999). The Entrenchment of Urban Dispersion: Residential Preferences and Location Patterns in the Dispersed City. *Urban Studies, 36*(8), 1317-1347. doi:10.1080/0042098993015

Handy, S. (1996). Urban Form and Pedestrian Choices: Study of Austin Neighborhoods. *Transportation Research Record: Journal of the Transportation Research Board, 1552*, 135-144. doi:10.3141/1552-19

Handy, S. (2005). *Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity*. Retrieved from

Handy, S. (2010). Walking, bicycling, and health. In S. Malekafzali (Ed.), *Healthy, Equitable Transportation Policy*. Oakland, CA: PolicyLink.
Handy, S. (2015). Community design and active travel. In R. Hickman, M. Givoni, B. David, & D. Banister (Eds.), *Handbook on Transport and Development* Cheltenham, UK: Edward Elgar Publishing.
Handy, S., Cao, X., & Mokhtarian, P. L. (2006). Self-Selection in the Relationship between the Built Environment and Walking: Empirical Evidence from Northern California. *Journal of the American Planning Association, 72*(1), 55-74. doi:10.1080/01944360608976724
Handy, S., Xing, Y., & Buehler, T. (2010a). Factors associated with bicycle ownership and use: a study of six small U.S. cities. *Planning - Policy - Research - Practice, 37*(6), 967-985. doi:10.1007/s11116-010-9269-x
Handy, S., Xing, Y., & Buehler, T. (2010b). Factors associated with bicycle ownership and use: a study of six small U.S. cities. *Transportation, 37*(6), 967-985. doi:10.1007/s11116-010-9269-x
Hansen, W. G. (1959). How Accessibility Shapes Land Use. *Journal of the American Institute of Planners, 25*(2), 73-76. doi:10.1080/01944365908978307
Harris, B. (2001). Accessibility: Concepts and Applications. *Journal of Transportation and Statistics, 4*(2/3), 15-30.
Hjorthol, R., Engebretsen, Ø., & Uteng, T. P. (2014). *The Norwegian Travel Survey 2013/14 – key results (in Norwegian language)* (https://www.toi.no/getfile.php?mmfileid=39511). Retrieved from Oslo: https://www.toi.no/getfile.php?mmfileid=39511
Hu, H., Xu, J., Shen, Q., Shi, F., & Chen, Y. (2018). Travel mode choices in small cities of China: A case study of Changting. *Transportation Research Part D: Transport and Environment, 59*, 361-374. doi:https://doi.org/10.1016/j.trd.2018.01.013
Kwan, M.-P. (2012). The Uncertain Geographic Context Problem. *Annals of the Association of American Geographers, 102*(5), 958-968. doi:10.1080/00045608.2012.687349
Kwan, M.-P., & Weber, J. (2008). Scale and accessibility: Implications for the analysis of land use–travel interaction. *Applied Geography, 28*(2), 110-123. doi:http://dx.doi.org/10.1016/j.apgeog.2007.07.002
Lindelöw, D., Svensson, Å., Brundell-Freij, K., & Winslott Hiselius, L. (2017). Satisfaction or compensation? The interaction between walking preferences and neighbourhood design. *Transportation Research Part D: Transport and Environment, 50*, 520-532. doi:http://dx.doi.org/10.1016/j.trd.2016.11.021
Marshall, W., Norman, G., & Stephen, M. (2015). Street networks. In R. Hickman, M. Givoni, B. David, & D. Banister (Eds.), *Handbook on Transport and Development*. Cheltenham, UK: Edward Elgar Publishing.
Milakis, D., Cervero, R., & van Wee, B. (2015). Stay local or go regional? Urban form effects on vehicle use at different spatial scales: A theoretical concept and its application to the San Francisco Bay Area. *2015, 8*(2). doi:10.5198/jtlu.2015.557
Mokhtarian, P. L., & Cao, X. (2008). Examining the impacts of residential self-selection on travel behavior: A focus on methodologies. *Transportation Research Part B, 42*(3), 204-228. doi:10.1016/j.trb.2007.07.006
Mokhtarian, P. L., & Salomon, I. (2001). How derived is the demand for travel? Some conceptual and measurement considerations. *Transportation Research Part A, 35*(8), 695-719. doi:10.1016/S0965-8564(00)00013-6
Nielsen, T. A. S., Olafsson, A. S., Carstensen, T. A., & Skov-Petersen, H. (2013). Environmental correlates of cycling: Evaluating urban form and location effects based on Danish micro-data. *Transportation Research Part D, 22*, 40-44. doi:10.1016/j.trd.2013.02.017
Næss, P. (2006). *Urban structure matters: residential location, car dependence and travel behaviour* (Vol. 13). London: Routledge.
Næss, P. (2009). Residential Self-Selection and Appropriate Control Variables in Land Use: Travel Studies. *Transport Reviews, 29*(3), 293-324. doi:10.1080/01441640802710812

Næss, P. (2012). Urban form and travel behavior: experience from a Nordic context. *2012, 5*(2). doi:10.5198/jtlu.v5i2.314
Næss, P. (2014). Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies. *Journal of Transport and Land Use, 7*(3), 23. doi:10.5198/jtlu.v7i3.491
Næss, P. (2015). Built Environment, Causality and Travel. *Transport Reviews, 35*(3), 275-291. doi:10.1080/01441647.2015.1017751
Næss, P., & Jensen, O. B. (2004). Urban structure matters, even in a small town. *Journal of Environmental Planning and Management, 47*(1), 35-57. doi:10.1080/0964056042000189790
Næss, P., Strand, A., Wolday, F., & Stefansdottir, H. (2017). Residential location, commuting and non-work travel in two urban areas of different size and with different center structures. *Progress in Planning*. doi:https://doi.org/10.1016/j.progress.2017.10.002
Ory, D. T., & Mokhtarian, P. L. (2005). When is getting there half the fun? Modeling the liking for travel. *Transportation Research Part A, 39*(2), 97-123. doi:10.1016/j.tra.2004.09.006
Pucher, J., & Buehler, R. (2010). Walking and Cycling for healthy cities. *Built Environment, 36*(4), 391-414.
Sallis, J. F., Owen, N., & Fisher, E. (2015). Ecological models of health behavior. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health behavior: theory, research, and practice* (pp. 43-64): San Francisco: Jossey-Bass.
Statistics Norway. (2015). Land use in urban settlements. Area and population of urban settlements, by densely populated area, contents and year. *Statistikkbanken, Table: 04859.* Retrieved from http://www.ssb.no
Stefansdottir, H. (2014). Urban routes and commuting bicyclist's aesthetic experience. *FORMakademisk, 7*(2). doi:10.7577/formakademisk.777
Sun, B., He, Z., Zhang, T., & Wang, R. (2016). Urban spatial structure and commute duration: An empirical study of China. *International Journal of Sustainable Transportation, 10*(7), 638-644. doi:10.1080/15568318.2015.1042175
Vilhelmson, B. (1999). Daily mobility and the use of time for different activities. The case of Sweden. *GeoJournal, 48*(3), 177-185. doi:10.1023/a:1007075524340
Wolday, F., Cao, J., & Næss, P. (2018). Examining factors that keep residents with high transit preference away from transit-rich zones and associated behavior outcomes. *Journal of Transport Geography, 66*(Supplement C), 224-234. doi:https://doi.org/10.1016/j.jtrangeo.2017.12.009
Ås, D. (1978). Studies of time-use: problems and prospects. *Acta Sociologica, 21*(4), 125-141.

Which factors cause people with high attitude towards active transport to underperform in their walk/bike trip frequency?

Fitwi Wolday *hamdwold@nmbu.no*
Department of Urban and Regional Planning, Norwegian University of Life Sciences (NMBU)
P.O. Box 5003, N-1432 Ås, Norway

Abstract
The amount of travel by active modes depends on how much a person is motivated to walk/bike and the extent to which the built environment allows for it. Instead of treating individuals across a wide spectrum of motivation (attitude) scale, this paper focuses on individuals with high positive attitude towards active transport but with below median levels of active transport (low-active-transport dissonant). Using survey data from three small cities, factors that characterize low-active-transport dissonant individuals are analyzed. Neighborhood accessibility, residential distance from the city center, family size, topography and employment are strongly associated with being dissonant. Moreover, the effect of built environment factors varies by trips purpose (facility category).

Keywords:
Small city, Active transport dissonance, Built environment, Facility categories

1. Background

This paper focuses on factors characterizing individuals with highly positive attitude towards active transport but who tend to travel less by active modes. Many studies document that individuals with different attitude levels tend to travel differently (Cao 2015a; Handy 2005; Handy et al. 2006; Næss 2006; Schwanen & Mokhtarian 2004). The motivation to commit oneself to travel actively is an important component of the travel behavioral outcome. The significance of motivation is even more pronounced in active travel decisions than travel by motorized modes (Cao et al. 2009b; Handy 2015). This is partly due to the physical exertion involved. Given other travel options, a person with unfavorable attitude towards active travel is unlikely to travel by active means. As a result, interventions intended to foster favorable attitude towards physical activity such as campaigns and educational programs are proposed as one of two powerful interventions in increasing physical activity (Barnes et al. 2013; Sallis et al. 2006); the other being interventions in the built environment.

The main question I address in this study is, given that there already is high positive attitude towards active transport, which factors hinder individuals with high positive attitude from realizing their active transport potential? Additionally, can certain neighborhood design aspects get them to increase their active travel frequency?

Besides destination accessibility, urban physical infrastructures that contribute to the safety and aesthetic experience are reported to contribute to higher rates of non-motorized travel (Akar & Clifton 2009; Buehler & Dill 2016; Handy 1996b; Stefánsdóttir 2014). For example, in a review of bikeway networks, Buehler and Dill (2016) indicate that cyclists and non-cyclists favor physically separated paths and/or lanes over cycling in roadways. In the UK Parkin et al. (2008) found that higher bike commuting was associated with higher proportions of off-road bike paths. Similarly, Tilahun et al. (2007) reported that respondents are willing to travel up to twenty minutes more to switch from an unmarked on-road facility to an off-road bicycle path. This paper will investigate whether the availability and quality of walk/bike paths will affect active travel magnitudes of individuals with high-positive attitude towards active transport but performing below median trips by active modes. In terms of geographic scale, this article focuses on small cities[1].

[1] The boundaries that distinguish cities between small, medium or large is blurry and greatly differs between countries. Small cities as used in this paper reflects the Scandinavian context and generally refers to cities with populations not exceeding 30 000 inhabitants.

One of the main sustainability objectives related to transportation is associated with reducing the magnitude of car travel. Various policy interventions (economic incentives, demand management, land-use planning) attempt to achieve this by moving people away from car-use for personal transport while at the same time making other alternative modes more attractive. However, transport modes that could be successfully utilized towards sustainability ends may depend, among others, on city size, as smaller size may limit the viability of alternative modes such as public transport (Wolday 2018a).

City size has important connotation for the adoption of appropriate transport mode strategies for sustainable mobility. In larger cities, where the critical population base required to support a frequent and efficient public transport provision is satisfied, both public transport and active modes can be utilized to reduce car use. If the city size is small, however, the reliability of public transport as a substitute for personal car may dissipate or the promised gains from investment in public transport systems may not materialize, as small cities are likely to lack economies of scale to support an efficient and frequent public transport service. On the other hand, the smaller size accords small cities with shorter distances between activity realms that makes non-motorized mode a feasible alternative for local travel. In addition, most small cities are monocentric in their center structure and with strong city centers offering concentrations of facilities that are potentially reachable by active travel modes. Accordingly, active travel has an indispensable role in reducing car-use in small cities.

In transportation and land-use research, for motorized and non-motorized modes alike, travel attitudes are often seen through the prism of travel-induced residential self-selection (RSS). The notion of RSS presupposes that individuals with a certain preferred mode of traveling tend to select their residential location in areas that enable them to travel by their preferred mode. For active transport, this would entail a tendency for individuals favoring walking/biking to choose neighborhoods that are conducive for active transport.

There are a couple of caveats associated with this understanding of the relationships between travel-related attitudes, residential choice, built environment (BE) and the resulting travel behavior. First, new studies (Ettema & Nieuwenhuis 2017; Wolday et al. 2018) that investigated the influence of travel-related attitudes on residential selection report that residential self-selection has marginal effect on travel behavior. Second, preferences, including travel related preferences, as the integral part of acquiring (demand for) services or goods do certainly influence residential location choice. However, in the hierarchy of importance, travel preferences as residential selection criteria are positioned as second tier below other, more important criteria (Cao 2008; Cao 2015b; Filion et al. 1999; Wolday et al. 2018).

Thirdly, individuals self-select towards but do not appear to self-select away from BE-features such as transit-oriented development (Wolday et al. 2018) and improvements in non-motorized transport infrastructure. This does not mean that people appreciate them equally or even use them equally. Individual responses vary depending on socio-demographics and idiosyncratic attributes like taste. Research in the field consistently report that, after accounting for differences in built environment, individuals with highly positive attitude towards active travel tend to travel more by such modes than those with less positive attitude (Cao 2008; Cao 2014; Chatman 2014; Næss 2006; Schwanen & Mokhtarian 2004). The heterogeneous response to BE factors among individuals due to differences in travel-related attitudes, however, cannot be automatically assumed to indicate travel-induced self-selection. If anything, it is more a proof of the influence of built environment on travel behavior (Næss 2009; Næss 2014).

Fourth, for non-motorized travel, the motivation to walk/bike (which can loosely be translated as the preference to walk/bike) is central to the outcome of actually walking/biking (Handy 2015; Sallis et al. 2006). Unsurprisingly, studies that accounted for self-selection found that travel attitudes had significant influence on active travel with large effect sizes (Cao et al. 2009a; Cao 2010). Often, results like this are ascribed to the confounding effects of travel attitudes through residential self-selection when, in fact, the direct effect of travel attitudes on active travel (through its influence on motivation) is more plausible.

This paper takes inspirations from ecological models in understanding and subsequently modeling the role of travel attitude in travel behavior. Ecological models marry built environment, intrapersonal and interpersonal variables in decoding the complex and multilayered nature of the relationships between built environment and travel behavior (Sallis et al. 2004; Sallis et al. 2006). Sallis et al. (2006) summarizes effective interventions towards physical activity as follows:

> *According to ecological models, the most powerful interventions should (1) ensure safe, attractive, and convenient places for physical activity; (2) implement motivational and educational programs to encourage use of those places; (3) use mass media and community organization to change social norms and culture.*

The fist point in the quotation refers to land-use policies, while the second and third points target individual motivations to engage in physical activity. These two sets of factors have their independent effects on travel behavior but they are also interconnected. The extent of active travel depends, on the one hand, on whether a person is motivated to travel by active modes and on the other hand on the degree to which the environment makes that choice both feasible and desirable (Handy 1996a; Handy 2010; Handy 2015; Ma et al. 2017).

Positive attitude towards active travel influences the extent of travel by non-motorized modes mainly via its direct influence on the motivation to commit oneself to travel by active modes. Individuals within the same neighborhood but with varying attitude levels towards non-motorized modes tend to travel differently. After accounting for socio-demographic and economic influences, those with high positive attitude to non-motorized travel tend to use non-motorized modes more than those who report lower positive attitude. Likewise, Individuals with the same level of attitude but residing in different neighborhoods do travel differently. Hence, the ultimate travel outcome depends on the person's motivation to walk/bike on the one hand and the built environment enabling her to utilize the preferred mode of travel on the other (Handy 2005; Ma et al. 2017; Sallis et al. 2006).

The paper is organized in five sections. The next section lays out the research questions followed by description of the data and methods used. Results and discussion appear in section four while section five covers the concluding remarks.

2. Research questions

The attitude towards, and therefore the motivation, to travel by active modes is an influential factor in deciding whether at all to travel by non-motorized transport and how much to travel (in terms of trips, time, and distance). Consequently, researchers and planners alike make a concerted effort to increase public awareness through campaigns and incentives (Barnes et al. 2013; Ma et al. 2017) with the ultimate goal of awakening people's interest in sustainable and healthy modes of mobility. Assuming that efforts such as campaigns and incentives are effective, which some studies show they are (Ma et al. 2017) in swaying people's attitude towards active travel, do individuals with high positive attitude to active travel respond with high magnitudes of walking/biking? This paper tries to answer this question by addressing the following two research questions:

- Among those with high positive attitude towards non-motorized travel, what distinguishes those with low levels of active transport (low-active-transport dissonants) from the ones whose travel patterns match their high positive attitude towards active transport (high-active-transport consonants)?

- For those who are motivated (individuals with high positive attitude) but currently performing low levels of active transport, which built environment characteristics can contribute to increase their active transport magnitude?

A comparison of groups with high and low trip frequencies among respondents with high positive attitude towards active transport is used to address the research questions. The study will explore built environment and socio-demographic factors that influence the likelihood of above or below median trip outcomes.

3. Data and method

3.1. Description of the study area

The study area comprises of three small cities from three different counties in southeastern Norway: Kongsvinger, Jessheim and Drøbak, with population size in their continuous built-up areas ranging between 11 000 and 17 000 (table 1). Population sizes in the built-up area are somewhat comparable in all three cities but in terms of population density, Kongsvinger appears to be more sparsely populated than Jessheim and Drøbak.

Table 1. Aggregate description of survey areas

Settlement areas (cities)	Number of residents	Area (km^2)	Density (residents/km^2)	Share of municipal population
Drøbak	13405	5.52	2428.4	86 %
Jessheim	16595	6.84	2426.2	51 %
Kongsvinger	11969	7.87	1520.8	67 %

Source: Statistics Norway, *Land use in urban settlements 2015.(Statistics Norway 2018)*

Another feature of significance to the discussions in this paper is the difference in the center structures of the case cities. Drøbak is dual centered with one old city-center (Torget) and another, main shopping-based center at the edge of the city. The city of Jessheim has a dense center in the middle of the city while the city of Kongsvinger has a single central zone but the concentration of facilities at the city center is not as dense as in Jessheim. In terms of distribution of facilities, Kongsvinger lies somewhere in between Jessheim and Drøbak (Wolday 2018b).

3.2. The survey

This section presents the sample and survey data in brief. A more detailed description of the survey data is covered by another articles (Wolday, 2018a).The data used in this study has been generated using a web-based survey sent to a sample of 15 000 residents in the three small cities of Kongsvinger, Jessheim and Drøbak. The sample was selected in two steps. First, residential units were identified in the continuous built-up area and almost all residential units that could be identified were included in the sample. This amounted to above 90 percent of all residential units in the three cities' built-up area. In the second step, an adult between the age of 18 and 75 was randomly selected from each residential unit.

An invitation letter was sent to each potential respondent in December 2015 with information on the purpose of the survey, how to access and complete the survey and contact information. The survey generated 1966 responses, a response rate of 13.1 percent.

3.3. Method

The data of interest in this paper involve individuals with high score in positive attitude towards active transport. In the survey, attitude towards active transport was measured using a five-point Likert scale where respondents were asked to indicate whether they agree or disagree with the statement "I prefer to walk/bike instead of driving whenever possible". The response alternatives ranged from disagree completely '1' to agree completely '5'. Respondents with an attitude score of '4' and '5', i.e. only those who have replied 'somewhat agree' and 'completely agree', are selected to represent residents with highly favorable attitude towards active transport.

Among the sub-sample of individuals with high positive attitude towards active transport, a distinction is made between those with high non-motorized trip frequency and the ones with low non-motorized trip frequency. The distinction is based on the group's median trip frequency, which is 14 trips per month to non-work destinations. Respondents with above median trip frequency are defined as ***high-active-transport consonants***, as their high positive attitude towards active travel matches their extent of active travel. The other half of the group with below median trip frequency are defined as ***low-active-transport dissonants***, because their high positive attitude mismatches their low trip frequency by non-motorized modes.

The dichotomous categorization of individuals between dissonant and consonant groups is inspired by Schwanen and Mokhtarian (2004) seminal work on the subject. In defining the consonant and dissonant residents, Schwanen and Mokhtarian (2004) matched individual attitudes with their neighborhood characteristics. In this paper, a slightly different definition is adopted. Instead of defining consonant and dissonant residents based on how individual attitudes match or mismatch their residential characteristics, individual's attitudes are matched with their active travel behavior. Furthermore, instead of taking the whole spectrum of attitude levels, I took only the high end of the spectrum. This led to only two groups instead of the more commonly used 2 X 2 classification (Cao 2015a; Wolday et al. 2018).

Table 2 shows the distribution of low and high non-motorized trip frequencies for varying levels of attitude towards active travel. As indicated by the last column, the low active travel dissonant has 461 observations whereas the high active travel dissonant has 443 respondents. To minimize the effect of extreme values[2] on model estimates, I limited the sub-sample to residential houses that are within 5 km from the city center. This reduced the net sample by 12 units (10 units from those with low levels of active travel and 2 from those with high levels of active travel).

Table 2. Distribution of respondents between low and high trip frequencies for different attitude levels

	Low level of active travel	**High level of active travel**	**Total**
Low positive attitude towards walking/biking	*357*	*76*	*433*
Neutral attitude towards walking/biking	*211*	*59*	*270*
High positive attitude towards walking/biking	**461**	**443**	**904**

Note: the categories for low and high trip frequency are set based on the median trip frequency for individuals with high positive attitude towards walking/biking.

In multivariate analysis (logistic regression), the match/mismatch between an individual's attitude for active transport and the self-reported magnitude of active transport is modeled using a dummy variable. Individuals whose active travel behavior mismatches their high positive attitude towards active modes (*low-active-transport dissonants*) assume the value '1' whereas those with both high positive attitude and a matching high trip frequency by active modes (*high-active-transport consonants)* assume the value '0'.

The dependent variable for the logistic regression analysis is a dummy variable reflecting *low-active-transport dissonance*. The independent variables in the analysis comprise of demographic variables (age, gender, household size, number of children), socio-economics (education level, income, employment status), urban structural attributes (residential distance from the city center, accessibility index, intersection density and topography) and car access[3]. Topography is measured using a five-point Likert

[2] Tukey's hinges (three Interquartile ranges) are used as outlier detection method.

[3] Controlling for car availability in this paper is not intended to mean that car access has to be controlled for due to its influence on residential choice. In fact, car ownership is more a result of a household's residential location than the other way around (Næss, 2009). In addition, the study here is not about travel distance by car but rather about trip frequency by active means. Therefore, controlling for car access is deemed necessary since the intention is to

item. Respondents were asked to indicate whether they agree or disagree with the statement 'the streets in my neighborhood are hilly which makes it difficult to bike". The topography variable enters the model as a continuous variable.

Since the effects of both accessibility and residential distance from the city center on non-work active trips vary by facility type (Wolday 2018b), three logistic regression models are developed: one, the model representing active transport to all facilities combined (termed as non-work facilities); two, a model for trips to center facilities; and three, a model for trips to grocery stores. Center facilities include commercial facilities for errands other than grocery shopping, eateries (restaurants and cafés) and medical facilities (clinics, dentist, pharmacies etc.). The rationale for the distinction of the facilities between center facilities and grocery stores relates to the relative degree of specialization and their likely location in the urban space.

Those with higher product diversification and providing specialized products tend to gain more from agglomeration and hence are likely to choose central locations. Conversely, firms providing less diversified goods and services may not gain as much from agglomeration. Another aspect influencing location decisions is the average trip frequency a person needs to make to a facility. Higher expected trip frequency per person means that the minimum threshold of potential customers is satisfied within a narrower range, to borrow Christaller's formulation (Christaller 1966).

Grocery stores mostly provide non-specialized, almost identical goods, making industry-level agglomeration less attractive. Grocery stores also have among the highest expected frequency of visits per person. Both characteristics, i.e. the non-specialized nature of the goods they provide and the higher expected number of visits per person make grocery stores to neighborhood facilities, with decentralization as a likely optimum location outcome. Center facilities benefit more from agglomeration effects and therefor are likely to be located in city centers together with other facilities where there is more urban vibrancy. Table 3 summarizes trip frequency by destination types.

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analyze the effect of built environment variables on walk/bike trip frequencies when other mobility alternatives are available.

Table 3. Description of non-motorized trip frequency by facility type

Facility type	Median trips per month	Mean trips per month	Standard deviation
Non-work facilities combined	14	16.78	13.69
Center facilities combined	4	5.72	5.80
Grocery stores	4	5.83	6.11

Note: Non-work facilities include center facilities, fitness facilities and grocery stores. Center facilities comprise of commercial facilities for errands other than grocery shopping, eateries (restaurants and cafés) and medical facilities (medical and dental clinics, pharmacies).

The survey data were supplemented with GIS-generated spatial data such as distance to various facilities and residential distance to the city center and a measure of street connectivity. Based on distance to facilities, a disaggregate accessibility index to facilities was computed within 805 meters (half-mile) from the residential homes. In order to accommodate the distance decay factor while at the same time accounting for attractiveness, the accessibility index was computed using a weighted gravity model based on Hansen's (1959) and Harris' (2001)[4] models.

Street network connectivity is often reported as an important component of neighborhood built environment characteristics and it is believed to have a significant influence on active transport (Marshall et al. 2015). In this paper, street network connectivity is defined as intersection density and is measured as the number of intersections (three way or more intersections) per unit area. The unit area is defined as a circular area around a residence with a half-mile (805 meters) radius. The calculation is performed using network analysis in ArcMap.

Besides the abovementioned independent variables, respondents provided information on walk/bike path characteristics that may induce them to walk/bike more than they did at the time of the survey by answering the survey question "to what extent can the following factors get you to walk/bike more than you currently do?" The factors comprise seven Likert items and an additional information in free text.

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[4] $A_{ij} = \sum_j W_{ij}\, e^{-C_{ij}}$

The accessibility indicator A_{ij} measures the accessibility of facility type *j* from residence i within an accessible range by an active mode. W_{ij} represents the number of facilities type *j* at a half-mile distance from residence i. The impedance factor is represented by $e^{-C_{ij}}$ where higher values of C_{ij} represents greater impedance to accessibility. The range accessible to residence i by active modes is defined as an area within 805 meters (half-mile) radius of the residence as the crow flies. Distance to facilities C_{ij} is measured along the street network.

The Likert items are measured in a five-point scale ranging between '1' "to a very small extent" and '5' "to a very large extent".

Apparently, many of the path characteristics measure very similar characteristics of the same underlying feature (active transport paths), and therefore are highly correlated. To avoid multicollinearity, the factors are collapsed from seven to two dimensions using exploratory factor analysis. These two dimensions relate to (1) the availability, quality and safety of walk/bike paths and (2) destination accessibility. Table 4 presents factor loadings of the individual components.

Table 4. Common dimensions extracted using exploratory factor analysis

	Availability and quality of walk/bike paths	**Destination accessibility**
Safe walk/bike paths	0,900	
Lighting on walk/bike paths	0,896	
Better marking and condition of walk/bike paths	0,888	
Good maintenance of walk/bike paths	0,872	
Existence of walk/bike paths	0,768	0,411
Residence near city center		0,889
Proximity to bus/train station	0,323	0,716

Note: Extraction Method: Principal Component Analysis with Kaiser Normalization. Loadings below 0.3 are suppressed.

4. Results and discussion

4.1. Descriptive statistics

Figure 1 shows the proportion of individuals with above median (AM) and below median (BM) monthly trip frequency to non-work destinations for each attitude category (for each point in the 5-point Likert item). The median trip frequency to non-work destinations is calculated as nine[5] trips per month.

For those with low positive attitude towards active transport, the proportion of individuals with below median trip frequencies is disproportionately larger but declines as attitude increases. Another noteworthy observation is that, for the respondents with high attitude (attitude categories 4 and 5), although the proportion with above median trip frequency is higher than that below median trip frequency, the proportion of respondents with below median trip frequency is still sizable and far from

[5] The median trip frequency of nine trips per month is for the sample as a whole. The median trip frequency used as a cut-off between dissonant and consonant residents is a little higher, fourteen trips per month, as it refers to the sub-sample of respondents with high attitude towards active travel.

insignificant. The question then is, among the individuals with high positive attitude to active travel, what distinguishes those with high trip frequency from those with low trip frequency?

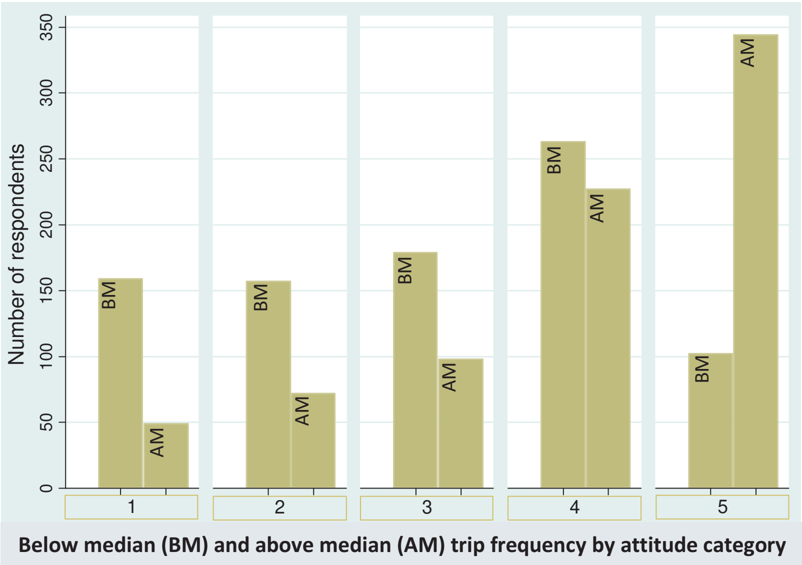

Figure 1. Number of respondents with below median (BM) and above median (AM) trip frequency by active modes for each attitude category

Based on the categorization of consonant and dissonant respondents, the following section describes factors that characterize the two sets of respondents.

4.2. Among those with high positive attitude to non-motorized travel, what distinguishes the low-active-transport dissonant from the high-active-transport consonant?

A significant number of respondents with high positive attitude towards walking/biking do travel by such modes below the groups' median trip frequency (figure 1 and table 2). To shed light on factors that characterize the discrepancy in trip frequency among the high positive attitude respondents, table 5 presents a comparison of the mean values of the relevant variables and the associated t-tests.

For most of the variables, with the exception of gender and topography, the differences between consonant and dissonant individuals are statistically significant as shown by the t-test (p-values in parenthesis). A comparison of the built environment attributes indicates that the low-active-transport dissonants reside in neighborhoods with lower intersection density, lower average accessibility to non-work facilities and live further away from the city center than their high-active-transport consonant counterparts. The mean comparisons also appear to show that they are richer, younger and have larger family size with more children. The low-active-transport dissonants also tend to have higher employment rate and higher levels of education and car access.

Table 5. Comparison of BE and socio-economic attributes between consonant and dissonant respondents

	Low-active-transport dissonant. N = 451*		**High-active-transport consonant. N = 441#**		**Difference**
	Mean	**Std. dev.**	**Mean**	**Std. dev.**	
Residential distance from the city center	1.986	0.942	1.520	1.001	0.467 (0.000)
Intersection density	258.082	101.461	300.905	127.359	-42.823 (0.000)
Accessibility to non-work facilities	5.247	10.991	14.850	23.953	-9.602 (0.000)
Accessibility to grocery stores	0.320	0.6443	0.939	1.156	-0.618 (0.000)
Accessibility to center facilities	4.927	10.573	13.911	23.082	-8.984 (0.000)
Household income per adult (1000 NOK)	513.116	195.931	475.339	205.263	37.778 (0.009)
Respondents age	50.448	12.595	53.408	14.780	-2.960 (0.001)
Household size	2.552	1.209	2.100	1.085	0.452 (0.000)
Number of children	0.876	1.037	0.505	0.941	0.372 (0.000)
Topography	2.310	1.470	2.159	1.386	0.152 (0.113)
Car availability	0.987	0.115	0.904	0.295	0.082 (0.000)
Gender (male=1)	0.457	0.499	0.431	0.496	0.026 (0.437)
Education (university degree=1)	0.672	0.471	0.594	0.492	0.078 (0.016)
Employment (employed=1)	0.787	0.410	0.621	0.486	0.166 (0.000)

Note: t-test p-values in parenthesis.
* Income has 399 observations while number of children has 380 observations
# Income has 384 observations while number of children has 329 observations

Many of the variables in table 5, although significantly different between the two groups, are likely to be correlated. Besides, to credibly infer the effect of, for example, built environment attributes on the likelihood of being dissonant, the effect of potentially confounding variables must be accounted for. A binary logistic regression is modeled to explore which factors, among the ones in table 5, may have a significant influence on low-active-transport dissonance when the effect of the rest of the variables on the outcome variable are controlled for. Table 6 reports the results.

Among the urban structure[6] attributes, residential distance from the city center, accessibility to non-work facilities and topography have a significant influence on the outcome variable. Residing further away from the city center and residing in neighborhoods with steeper terrain increases the probability of being low-active-transport dissonant, i.e. traveling less by active modes despite having higher positive attitude towards them. Having higher accessibility to non-work facilities, on the other hand, reduces the likelihood of low-active-transport dissonance. Looking at the standardized coefficients, accessibility to

[6] Urban structure is used here (distinctly from the term built environment) to refer to both the built structures and natural structures such as topography.

non-work facilities has the strongest influence. Again, this is consistent with many previous findings (Cao et al. 2006; Ewing & Cervero 2010; Handy & Clifton 2001).

From the socio-demographic attributes, employment and larger household size tend to lead to fewer trips by non-motorized modes as expected, despite high positive attitude towards active modes. Car availability also tends to increase the probability of being low-active-transport dissonant.

Table 6. Factors influencing the likelihood of low-active-transport dissonance

	Coefficient.	**Robust std. err.**	**P-value**
Residential distance from the city center	0.3037 (0.145)	.0895	0.001
Accessibility to non-work facilities	-0.0286 (-0.262)	.0076	0.000
Household size	0.1650 (0.096)	.0651	0.011
Employment	0.6744 (0.147)	.1696	0.000
Car availability	1.7475 (0.189)	.4711	0.000
Topography	0.1651 (0.113)	.0534	0.002
Constant	-3.1832	.5396	0.000
Number of observations	*889*		
Nagelkerke R^2	*0.201*		

Note: standardized estimates in parenthesis.

The results in table 6 are straightforward in that, as one goes further away from the city center the average accessibility to non-work facilities decreases and so does also the average trip frequency even for those with favorable attitude to walking/biking.

The three cities, as explained in section 3.1, differ in terms of their center structures. The city of Jessheim has the densest city center with high concentration of facilities followed by Kongsvinger, whereas Drøbak has a diffused center structure with two different centers comprising of service and commercial facilities. When cities have different center structures, residential distance from the city center are not directly comparable across cities. Therefore, a city dummy is introduced to test whether the likelihood could differ between cities. The results show no difference between the cities (results for the city dummy are insignificant and therefore not reported).

It is also less likely that accessibility to non-work facilities would uniformly and simultaneously decline across all facility categories as one moves away from the city center. This is because firms' optimal location decisions are influenced by product diversification and specialization of their core functions. The effect of residential location is therefore expected to vary by facility type depending on whether centralization or decentralization is the firm's likely optimal location choice (Wolday 2018b). To account for the potential difference in the effect of BE-attributes on trip frequency by facility type, I rerun the same model specification in table 6, but this time the non-work walk/bike trips are grouped by trip purpose in to two categories: trips to center facilities and trips to grocery stores (trips to fitness facilities are excluded). Table 7 shows the results.

For non-motorized trips to grocery stores, neighborhood accessibility is the most important variable in reducing the likelihood of low-active-transport dissonance. The standardized estimates also show that neighborhood accessibility has the strongest effect. Individuals with high positive attitude towards non-motorized travel but who currently are infrequent users of active modes to grocery stores are likely to increase their active transport to grocery stores as accessibility increases. Conversely, large households, employment and car availability tend to increase the likelihood of low-active-transport dissonance.

When it comes to active travel to center facilities, the likelihood of being dissonant is higher when one lives further away from the city center. Distance from the city center commands the strongest influence. Higher neighborhood accessibility to center facilities reduces the likelihood of dissonance but the effect is lower than that of residential distance from the city center. People living in hilly neighborhoods (topography) have a higher likelihood of being dissonant. Among the socio-economic variables, only employment is significant.

Table 7. Likelihood of low-active-transport dissonance by trip purpose with Robust Standard error.

	Grocery stores			**Center facilities**		
	Coefficients	**Robust std. err.**	**P-value**	**Coefficients**	**Robust std. err.**	**P-value**
Residential distance from the city center	-	-	*Insig*.	0.740 (0.347)	.098	0.000
Accessibility to grocery stores	-1.024 (-0.457)	.149	0.000	-	-	-
Accessibility to center facilities	-	-	-	-0.022 (-0.194)	.008	0.004
Household size	0.231 (0.125)	.078	0.003	0.176 (0.102)	.068	0.010
Employment	0.556 (0.113)	.189	0.003	0.641 (0.135)	.192	0.001
Car availability	2.274 (0.229)	.597	0.000	-	-	*Insig*.
Topography	-	-	*Insig*.	0.229 (0.151)	.058	0.000
Constant	-2.257	.6287	0.000	-2.697	.329	0.000
Number of observations	*744*			*815*		
Nagelkerke R^2	*0.299*			*0.259*		

Note: standardized estimates in parenthesis. Insignificant estimates are marked as *Insig*.

4.3. *What can get individuals with high positive attitude but fewer trips by active travel to increase the magnitude of active travel?*

Based on survey responses to the question "what can get you to walk/bike more than you currently do?" I calculated mean score and then a difference between dissonant and consonant respondents for each Likert item (results in table 8). The mean score for the dissonant and consonant residents are very close as shown by the difference presented in the last column. The ranking of the mean scores (reported in parenthesis), which indicates the relative importance of the items, is also identical for both groups signifying the items are important to both consonant and dissonant individuals. The slight positive difference means that the items are slightly more important for the dissonant respondents than for the consonant respondents and vice versa for the negative difference.

Table 8. Comparison of neighborhood factors perceived to increase active travel magnitude.

	Low-active-transport dissonant. N=438		High-active-transport consonant. N=449		
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Difference**
Good maintenance of walk/bike paths	4,025 (1)	1.119	3,976 (1)	1.086	5 %
Lighting on walk/bike paths	3,977 (2)	1.136	3,864 (2)	1.156	11 %
Safe walk/bike paths	3,878 (3)	1.196	3,849 (3)	1.167	3 %
Existence of walk/bike paths	3,786 (4)	1.225	3,735 (4)	1.189	5 %
Better marking and condition of walk/bike paths	3,548 (5)	1.252	3,628 (5)	1.187	-8 %
Proximity to bus/train station	3,420 (6)	1.470	3,488 (6)	1.458	-7 %
Residence near city center	2,991 (7)	1.477	2,882 (7)	1.373	11 %

Note: Ranking among the alternative walk/bike path characteristics in parenthesis.

To investigate the likelihood of factors related to walk/bike paths (table 8) augmenting active travel of the low-active-transport dissonants more than their high-active-transport consonant counterparts, a logistic regression was modelled.

The logistic regression models low-active-transport dissonant on the two factor components (section 3.2), with socio-demographics, built environment attributes, topography and car availability as control variables. Table 9 reports results from the logistic regression.

Table 9[7]. Factors reducing the likelihood of low-active-transport dissonance

	Coefficients	Robust Std. Err.	P-value
Residential distance from the city center	0.3027 (0.145)	.0898	0.001
Accessibility to non-work facilities	-.0284 (-0.260)	.0076	0.000
Availability & quality of walk/bike paths	-.0308 (-0.014)	.0777	0.691
Destination accessibility	-.0145 (-0.007)	.0709	0.838
Household size	0.1629 (0.095)	.0652	0.012
Employment	0.6749 (0.147)	.1702	0.000
Car availability	1.7378 (0.187)	.4770	0.000
Topography	0.1632 (0.112)	.0534	0.002
Constant	-3.1561	.5434	0.000
Number of observations	884		
Nagelkerke R^2	0.199		

Note: - Standardized estimates in parenthesis.

The two factor variables turned out to be insignificant. This is likely because these factors are equally important for both groups of individuals (dissonants and consonants). A t-test (not reported) of the difference in scores for each walk/bike path item between the dissonant and consonant groups (table 8) is also insignificant, which further supports the argument that the items (and indeed the two factor variables) are important for both groups.

Taking the sample as a whole (without distinguishing between high and low attitude individuals), however, availability of well-maintained and safe walk/bike path significantly increases the magnitude of active transport. These results are in line with previous findings (Buehler & Dill 2016; Parkin et al. 2008). The result of multivariate OLS regression of the effect of walk/bike paths on non-motorized trip frequency is presented by table A1 in the appendix.

4.4. Limitations

The data utilized in this paper combines walking and biking trips together. Lumping up biking and walking together and treating them as though they are a single mode may lead to a limitation known as unidentified geographic context problem or in short UGCoP (Kwan & Weber 2008; Kwan 2012), which refers to a bias associated with arbitrarily identifying the effective zones of a travel mode. Since walking and biking have different effective zones (Nielsen et al. 2013), combining both modes into one may miss certain nuances as to which built environment variables are effective in promoting either mode.

---

[7] Independent variables specified in the model include the two factor variables (walk/bike path characteristics & destination accessibility), socio-demographic variables (age, gender, income, education, employment), built environment variables (residential distance from the city center, accessibility index & intersection density), topography, car availability and city dummy. Estimates of the factor variables, although insignificant, are included in the table as they are key variables in the analysis.

However, the neighborhood characteristics that influence both modes are largely similar. Moreover, the number of walking trips greatly surpasses biking trips. The Norwegian average for smaller cities shows that walking accounts for about 81 per cent of active travel trips according the recent National Travel Survey from 2013/2014 (Hjorthol et al. 2014). Given that the aim of this paper is to identify influential factors (built environment and socio-demographic attributes) on active transport in a multivariate regression setting, I maintain that combining both biking and walking will not be a major source of bias.

5. Conclusion

Previous research findings conclude that, given the availability of alternative means of mobility, an individual without a motivation to walk or bike is unlikely to do so. Using survey data from three small cities, and analyzing factors that characterize individuals with high positive attitude towards active transport, this paper attempted to answer the following questions: Which factors are likely to cause low levels of active transport among high-positive-attitude individuals? And, can neighborhood design factors (walk/bike path characteristics) get dissonant residents to increase their active transport magnitude?

Using a combination of descriptive and binary logistic analysis, this paper finds that low average accessibility to non-work facilities, residential distance from the city center, topography, car access, family size, and employment are associated with being low-active-transport dissonant. Accessibility to non-work facilities and proximity to the city center are the two most influential variables that increase the likelihood of higher walk/bike rates among dissonant individuals (individuals with high positive attitude to active transport but traveling below median levels by active modes). Employment and large family size also tend to cause residents to be dissonant. Neighborhood design factors related to walk/bike paths do not influence walk/bike rates of dissonant individuals more than they do for consonant individuals, as they are equally important to both categories of residents.

An analysis of walk/bike trips by trip purpose shows the effect of built environment factors on the likelihood of being low-active-transport dissonant varies by facility category. For trips to grocery stores, neighborhood accessibility is the most influential variable. For center facilities, although neighborhood accessibility index is also important, proximity to the city center exerts the strongest influence.

In light of the findings in this paper and previous related studies, urban planners who intend to increases walk/bike rates in small-city regions have to avoid leapfrog type developments that unduly increases the average distance from the city center. New residential neighborhoods should also be planned in such a way that support basic neighborhood facilities such grocery stores.

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Appendix

Table A1. Effect of walk/bike path characteristics on non-work active transport

WBnonwork1	**Coefficient**	**Robust std. err.**	**P-value**
Residential distance from the city center	-2.4778 (-0.192)	.3521	0.000
Accessibility to non-work facilities	0.0912 (0.124)	.0227	0.000
Availability & quality of walk/bike paths	1.4458 (0.112)	.2973	0.000
Destination accessibility	0.1818 (0.014)	.3097	0.557
Household size	-.4427 (-0.042)	.2783	0.112
Employment	-4.2631 (-0.149)	.7501	0.000
Car availability	-9.0783 (-0.136)	2.0847	0.000
Topography	-1.1760 (-0.134)	.1980	0.000
Constant	32.5745	2.3412	0.000
Number of observations	1625		
Adjusted R^2	0.157		

Note: Although trips frequency is a count data the number of count is large and can be modeled as linear regression. Furthermore, a robust standard error is used to accommodate the non-negative integer property of the data that is likely to result in a non-uniform variance (homoscedasticity).

References

Akar, G. & Clifton, K. (2009). Influence of individual perceptions and bicycle infrastructure on decision to bike. *Transportation Research Record: Journal of the Transportation Research Board* (2140): 165-172.

Barnes, R., Giles-Corti, B., Bauman, A., Rosenberg, M., Bull, F. & Leavy, J. (2013). Does neighbourhood walkability moderate the effects of mass media communication strategies to promote regular physical activity? *Annals of Behavioral Medicine*, 45 (1): 86-94.

Buehler, R. & Dill, J. (2016). Bikeway Networks: A Review of Effects on Cycling. *Transport Reviews*, 36 (1): 9-27.

Cao, X., Handy, S. L. & Mokhtarian, P. L. (2006). The Influences of the Built Environment and Residential Self-Selection on Pedestrian Behavior: Evidence from Austin, TX. *Transportation*, 33 (1): 1-20.

Cao, X. (2008). Is Alternative Development Undersupplied? Examination of Residential Preferences and Choices of Northern California Movers. *Transportation Research Record: Journal of the Transportation Research Board*, 2077: 97-105.

Cao, X., Mokhtarian, P. L. & Handy, S. L. (2009a). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A: Policy and Practice*, 43 (5): 548-559.

Cao, X., Mokhtarian, P. L. & Handy, S. L. (2009b). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A*, 43 (5): 548-559.

Cao, X. (2010). Exploring Causal Effects of Neighborhood Type on Walking Behavior Using Stratification on the Propensity Score. *Environment and Planning A*, 42 (2): 487-504.

Cao, X. (2014). Examining the impacts of neighborhood design and residential self-selection on active travel: a methodological assessment. *Urban Geography*: 1-20.

Cao, X. (2015a). Heterogeneous effects of neighborhood type on commute mode choice: An exploration of residential dissonance in the Twin Cities. *Journal of Transport Geography*, 48: 188.

Cao, X. (2015b). Residential Preference and Choice of Movers in Light Rail Neighborhoods in Minneapolis, Minnesota. *Transportation Research Record: Journal of the Transportation Research Board*, 2494: 1-10.

Chatman, D. G. (2014). Estimating the effect of land use and transportation planning on travel patterns: Three problems in controlling for residential self-selection. *Journal of Transport and Land Use; Vol 7, No 3 (2014)*.

Christaller, W. (1966). *Central places in southern Germany*. Englewood Cliffs, N.J.: Prentice-Hall. 230 s. : ill. pp.

Ettema, D. & Nieuwenhuis, R. (2017). Residential self-selection and travel behaviour: What are the effects of attitudes, reasons for location choice and the built environment? *Journal of Transport Geography*, 59: 146-155.

Ewing, R. & Cervero, R. (2010). Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association*, 76 (3): 265-294.

Filion, P., Bunting, T. & Warriner, K. (1999). The Entrenchment of Urban Dispersion: Residential Preferences and Location Patterns in the Dispersed City. *Urban Studies*, 36 (8): 1317-1347.

Handy, S. (1996a). Methodologies for exploring the link between urban form and travel behavior. *Transportation Research Part D: Transport and Environment*, 1 (2): 151-165.

Handy, S. (1996b). Urban Form and Pedestrian Choices: Study of Austin Neighborhoods. *Transportation Research Record: Journal of the Transportation Research Board*, 1552: 135-144.

Handy, S. (2005). Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity. *Does the Built Environment Influence Physical Activity? Examining the*

Evidence: Prepared for the Transportation Research Board and the Institute of Medicine Committee on Physical Activity, Health, Transportation and Land Use.
Handy, S., Cao, X. & Mokhtarian, P. L. (2006). Self-Selection in the Relationship between the Built Environment and Walking: Empirical Evidence from Northern California. *Journal of the American Planning Association*, 72 (1): 55-74.
Handy, S. (2010). Walking, bicycling, and health. In Malekafzali, S. (ed.) *Healthy, Equitable Transportation Policy*. Oakland, CA: PolicyLink.
Handy, S. (2015). Community design and active travel. In Hickman, R., Givoni, M., David, B. & Banister, D. (eds) *Handbook on Transport and Development* Cheltenham, UK: Edward Elgar Publishing.
Handy, S. L. & Clifton, K. J. (2001). Local shopping as a strategy for reducing automobile travel. *Transportation*, 28 (4): 317-346.
Hansen, W. G. (1959). How Accessibility Shapes Land Use. *Journal of the American Institute of Planners*, 25 (2): 73-76.
Harris, B. (2001). Accessibility: Concepts and Applications. *Journal of Transportation and Statistics*, 4 (2/3): 15-30.
Hjorthol, R., Engebretsen, Ø. & Uteng, T. P. (2014). The Norwegian Travel Survey 2013/14 – key results (in Norwegian language), https://www.toi.no/getfile.php?mmfileid=39511. Oslo: Norwegian Center for Transport Research: TØI Report 1383/2014. 140 pp.
Kwan, M.-P. & Weber, J. (2008). Scale and accessibility: Implications for the analysis of land use–travel interaction. *Applied Geography*, 28 (2): 110-123.
Kwan, M.-P. (2012). The Uncertain Geographic Context Problem. *Annals of the Association of American Geographers*, 102 (5): 958-968.
Ma, L., Mulley, C. & Liu, W. (2017). Social marketing and the built environment: What matters for travel behaviour change? *Transportation*, 44 (5): 1147-1167.
Marshall, W., Norman, G. & Stephen, M. (2015). Street networks. In Hickman, R., Givoni, M., David, B. & Banister, D. (eds) *Handbook on Transport and Development*. Cheltenham, UK: Edward Elgar Publishing.
Nielsen, T. A. S., Olafsson, A. S., Carstensen, T. A. & Skov-Petersen, H. (2013). Environmental correlates of cycling: Evaluating urban form and location effects based on Danish micro-data. *Transportation Research Part D*, 22: 40-44.
Næss, P. (2006). *Urban structure matters: residential location, car dependence and travel behaviour*. The RTPI library series, vol. 13. London: Routledge.
Næss, P. (2009). Residential Self-Selection and Appropriate Control Variables in Land Use: Travel Studies. *Transport Reviews*, 29 (3): 293-324.
Næss, P. (2014). Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies. *Journal of Transport and Land Use*, 7 (3): 23.
Parkin, J., Wardman, M. & Page, M. (2008). Estimation of the determinants of bicycle mode share for the journey to work using census data. *Transportation*, 35 (1): 93-109.
Sallis, J. F., Frank, L. D., Saelens, B. E. & Kraft, M. K. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. *Transportation Research Part A: Policy and Practice*, 38 (4): 249-268.
Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K. & Kerr, J. (2006). An ecological approach to creating active living communities. *Annu. Rev. Public Health*, 27: 297-322.
Schwanen, T. & Mokhtarian, P. L. (2004). The extent and determinants of dissonance between actual and preferred residential neighborhood type. *Environment and planning. B, planning and design*, 31: 759-8135.
Statistics Norway. (2018). *Population projections in municipalities. 2018-2040.* Population statistics. Available at: http://www.ssb.no (accessed: July 30).

Stefánsdóttir, H. (2014). Urban routes and commuting bicyclists' aesthetic experiences. *Form Akademisk-forskningstidsskrift for design og designdidaktikk*, 7 (2).
Tilahun, N. Y., Levinson, D. M. & Krizek, K. J. (2007). Trails, lanes, or traffic: Valuing bicycle facilities with an adaptive stated preference survey. *Transportation Research Part A: Policy and Practice*, 41 (4): 287-301.
Wolday, F. (2018a). Built environment and car driving distance in a small city context. *Journal of Transport and Land Use*, Forthcoming.
Wolday, F. (2018b). The effect of neighborhood and urban center structures on active travel in small cities. *(Under review)*.
Wolday, F., Cao, J. & Næss, P. (2018). Examining factors that keep residents with high transit preference away from transit-rich zones and associated behavior outcomes. *Journal of Transport Geography*, 66 (Supplement C): 224-234.

Appendix

Travel behavior in small cities

A survey in residential location and travel behavior in Kongsvinger, Jessheim and Drøbak.

1. Background information

1.1 Dwelling type

☐ Single-family house ☐ Duplex ☐ Row house, etc.

☐ Apartment ☐ Other dwelling type (pls specify) ____________________

1.3. Current residential address

Str. No.: ____
Postal code: __________ City/place: ________________________________

1.2. Time of residence in current dwelling

☐ less than 2 yrs ☐ 2 – 5 yrs ☐ 5 – 10 yrs ☐ more than 10 yrs

➔ *Proceed to question 1.7 if you have lived 5 or more years in your current residence*

1.4. If you have lived in your current dwelling less than 5 years, please specify your previous address

Str. No.: ____
Postal code: __________ City/place: ________________________________

1.5. If you have moved during the last 5 years, did your move cause change in your travel behavior? This refers to change in travel behavior as a result of physically moving to a new location. Choose multiple alternatives if necessary.

☐ Yes, I walk more now
☐ Yes, I bike more now
☐ Yes, I drive more now
☐ Yes, I use public transport more now
☐ Yes, I walk less now
☐ Yes, I bike less now
☐ Yes, I drive less now
☐ Yes, I use public transport less now
☐ No, almost unchanged
☐ My travel pattern changed but for reasons other than the move

1.6. Did your travel activity change due to reasons other than the move? *Change in travel activity not specifically related to the move, but due to life cycle change for e.g. that, the household has more children than before the move, etc.*

□ Yes □ No

If yes, please specify the reasons for change in travel activity: ____________________________

1.7. Please indicate how important each of the following residential characteristics are if you were to move to a new dwelling on a scale from "not at all important" to "highly important". *If some of the characteristics are irrelevant, tick the box for designated for this*.

	not considered	Not important at all			Highly important
	0	**1**	**2**	**3**	**4**
Nice view from the dwelling	□	□	□	□	□
Proximity to green areas	□	□	□	□	□
Low housing costs (i.e. low rent, low monthly mortgage, etc.)	□	□	□	□	□
Proximity to grocery shops	□	□	□	□	□
Undisturbed location	□	□	□	□	□
Proximity to relatives and friends	□	□	□	□	□
Proximity to workplace	□	□	□	□	□
Proximity to train station	□	□	□	□	□
Proximity to bus stop	□	□	□	□	□
Proximity to city center	□	□	□	□	□
Private garden	□	□	□	□	□
High architectural and esthetic quality	□	□	□	□	□
Location in a familiar neighborhood	□	□	□	□	□
Good school/kindergarten	□	□	□	□	□
No social problems in the neighborhood	□	□	□	□	□
Favorable investment object	□	□	□	□	□
Proximity to shopping facilities	□	□	□	□	□
Easy access to shopping mall	□	□	□	□	□
Not close to major road/rail line	□	□	□	□	□
Opportunities for physical exercise in the neighborhood	□	□	□	□	□
Good property management	□	□	□	□	□

2. Arbeidsreiser

2.1. Are you for the time being a workforce participant (fulltime or part-time at least one hour a week) or under education?

□ Yes, I am a workforce participant

□ Yes, I am a student/pupil

□ No, I am neither workforce participant nor student/pupil

➔ *If you are neither a workforce participant nor a student, proceed to question **3.1**.*

2.2. What is your occupation?

Provide a detailed description as possible. Example: If "teacher" write "teacher, elementary school", etc.

____

2.3. How far is it in kilometers from your residence to your primary place of work/education?

______________ km

2.4. How long does it usually take to get from home to your primary place of work/education by the mode of transport you use most frequently? ______________ minutes

2.5. Please write the addresses of your workplace and/or place of education.

What we ask for is the address of the premises where you actually show up for your work or education, not the address of any differently located administration headquarter. If you do not know the exact address, please indicate the location as precisely as you can in another way, e.g. by indicating the name of the neighborhood, closest major street crossing, or the closest metro/streetcar/bus stop.

Workplace:

Street name and address: ____

Postal code: ___________ City/Place: ____

Educational location:

Street name and address: ____

Postal code: ___________ City/Place: ____

2.6. How many days do you normally commute to place of work/education per week? ______ days

2.7. In a typical month in autumn, how many days do you use each of the following as your *primary* mode of transportation between home and work/education? By "primary" we mean the mode of transportation you use for the longest portion of your trip.

	Not applicable	Less than a day per ***week***	1-2 days per ***week***	3-4 days per ***week***	Greater than 4 days per ***week***
Working at home instead of making the trip	□	□	□	□	□
Walking	□	□	□	□	□
Biking	□	□	□	□	□
Car	□	□	□	□	□
Train	□	□	□	□	□
Bus	□	□	□	□	□
Motor bike, moped or scooter	□	□	□	□	□
Boat/ferry	□	□	□	□	□
Other (Please specify)	□	□	□	□	□

2.8. If your commute to work/education requires combinations of multiple modes, please list them according to travel distance covered by each of them in a typical day in the autumn. Do not include walking distances with less than 5 minutes duration while changing between transport modes.

Reiseavstand	Transportformer (tog, buss, bil, sykkel, etc.)	Lengde i KM (en vei)
Longest travel distance		
Next longest travel distance		
Third longest travel distance		
Fourth longest travel distance		

3. Non-work travel

3.1. Do you regularly escort child/children to and from kindergarten, school or leisure activities?

□ Yes □ No

3.2. In a typical month during the autumn, how often do you walk or bike from home to each of the following destinations? *Do not include trips related to work/education.*

	None	Under a day per ***month***	1-3 days per ***month***	One day per ***week***	2-3 days per ***week***	4 or more days a ***week***
Civic or religious places (library, church, mosque etc.)	□	□	□	□	□	□
Service provider (ex., bank, hairdresser)	□	□	□	□	□	□
Grocery stores	□	□	□	□	□	□
Restaurants or Coffee shops	□	□	□	□	□	□
Other errands (other than grocery shopping)	□	□	□	□	□	□
Place for entertainment/culture	□	□	□	□	□	□
place to exercise (ex., a gym, a sports hall or a park)	□	□	□	□	□	□
Accompany children to school/day care	□	□	□	□	□	□
Place where you pick up or drop off a passenger to/from sports or related activity	□	□	□	□	□	□
Medical services (doctor’s office/hospital, dental clinics, etc.)	□	□	□	□	□	□
Visits (visiting family and friends)	□	□	□	□	□	□

3.3. In a typical month during the autumn, how often do you drive a car to each of the following destinations? ***Do not include trips related to work/education.***

	None	Under a day per ***month***	1-3 days per ***month***	One day per ***week***	2-3 days per ***week***	4 or more days a ***week***
Civic or religious places (library, church, mosque etc.)	◻	◻	◻	◻	◻	◻
Service provider (ex., bank, hairdresser)	◻	◻	◻	◻	◻	◻
Grocery stores	◻	◻	◻	◻	◻	◻
Restaurants or Coffee shops	◻	◻	◻	◻	◻	◻
Other errands (other than grocery shopping)	◻	◻	◻	◻	◻	◻
Place for entertainment/culture	◻	◻	◻	◻	◻	◻
Place to exercise (ex., a gym, a sports hall or a park)	◻	◻	◻	◻	◻	◻
Accompany children to school or day care	◻	◻	◻	◻	◻	◻
Place where you pick up or drop off a passenger to/from sports or related activity	◻	◻	◻	◻	◻	◻
Medical services (doctor's office/hospital, dental clinics, etc.)	◻	◻	◻	◻	◻	◻
Visits (visiting family and friends)	◻	◻	◻	◻	◻	◻
Shopping trips to place outside your city	◻	◻	◻	◻	◻	◻

3.4. In a typical month during the autumn, how often do you travel by public transport from your home to each of the following destinations? *Do not include trips related to work/education.*

	None	Under a day per ***month***	1-3 days per ***month***	One day per ***week***	2-3 days per ***week***	4 or more days a ***week***
Civic or religious places (library, church, mosque etc.)	◻	◻	◻	◻	◻	◻
Service provider (ex., bank, hairdresser)	◻	◻	◻	◻	◻	◻
Grocery stores	◻	◻	◻	◻	◻	◻
Restaurants or Coffee shops	◻	◻	◻	◻	◻	◻
Other errands (other than grocery shopping)	◻	◻	◻	◻	◻	◻
Place for entertainment/culture	◻	◻	◻	◻	◻	◻
place to exercise (ex., a gym, a sports hall or a park)	◻	◻	◻	◻	◻	◻
Accompany children to school or day care	◻	◻	◻	◻	◻	◻
Place where you pick up or drop off a passenger to/from sports or related activity	◻	◻	◻	◻	◻	◻
Medical services (doctor's office/hospital, dental clinics, etc.)	◻	◻	◻	◻	◻	◻
Visits (visiting family and friends)	◻	◻	◻	◻	◻	◻
Shopping trips to place outside your city	◻	◻	◻	◻	◻	◻

3.5. Approximately how many kilometers do you travel as a car driver in a typical week during the autumn? *Do not include driving as part of your workday, such as business trips to customers or meetings. If you do not travel as a car driver, then please write 0 (zero).*

In total over the weekdays (Monday-Friday): _______ km

In total during the weekend (Saturday-Sunday): _______ km

3.6. Approximately how many kilometers do you travel on foot or by bike within the municipality you live in in a typical week during the autumn? *Do not include trips taken as part of your workday (such as business trips to customers or meetings) and trips as part of sporting activities (jogging, walking or biking). If you do not travel by non-motorized modes, then please write 0 (zero).*

In total over the weekdays (Monday-Friday): _______ km

In total during the weekend (Saturday-Sunday): _______ km

3.7. Approximately how many kilometers do you travel by public transport within the municipality you live in in a typical week during the autumn? *Do not include driving as part of your workday, such as business trips to customers or meetings. If you do not travel as a car driver, then please write 0 (zero).*

In total over the weekdays (Monday-Friday): _______ km

In total during the weekend (Saturday-Sunday): _______ km

3.8. Please state the number of motor vehicles normally available for the household as private means of daily transport. *Include cars owned by the household, company cars, leased cars etc. available for private driving.*

Number of cars (including ordinary cars as well as vans ___________________

Number of two-wheeled motor vehicles (motorcycles, scooters, mopeds) ___________________

3.7. How long one-way travel time do you consider the longest acceptable in order to reach the following destinations?

	Less than 5 minutes	Between 5 and 15 minutes	Between 15 and 30 minutes	Between 30 and 45 minutes	More than 45 minutes	Destination not relevant
Place of work/education	□	□	□	□	□	□
Kindergarten/ primary school	□	□	□	□	□	□
Grocery store	□	□	□	□	□	□
Place for pursuing regular physical exercise	□	□	□	□	□	□
Coffee place/restaurant	□	□	□	□	□	□
Movie theater	□	□	□	□	□	□
Public library	□	□	□	□	□	□

4. Socio-economic and demographic information

4.1. Please specify your gender and year of birth Male □ Female □ Year of birth __________

4.2. Does the household include other members besides yourself? Household members refers to persons with a permanent residence in the same dwelling as you are.

□ **Yes** □ No

➔ *If your answer to question 4.2 is `No`, proceed to question 4.4.*

4.3. Please indicate the number of household members (including yourself) under the specified age groups.

Under 7 years: _____ persons; 7 -11 years: _____ persons; 12 -17 years: _____ persons; 18 years or above: _____ persons

4.4. What is your highest level of education attained?

Elementary school □
High school or professional secondary school □
College/University – up to 4 years □
College/university – 5 years or more □

4.5. Please indicate your annual personal income (before tax gross income).

Under 100 000 kr □
100 000 – 199 999 kr □
200 000 – 299 999 kr □
300 000 – 399 999 kr □
400 000 – 499 999 kr □
500 000 – 599 999 kr □
600 000 – 699 999 kr □
700 000 – 799 999 kr □
800 000 kr eller mer □
Don’t know □

4.6. Please indicate total annual income for your household (before tax gross income).

Under 200 000 kr □
200 000 – 399 999 kr □
400 000 – 599 999 kr □
600 000 – 799 999 kr □
800 000 – 999 999 kr □
1000 000 – 1199 999 kr □
1200 000 kr eller mer □
Don’t know □

5. Dwelling and transport related preferences and attitudes

5.1. Do you consider yourself as car dependent for your daily activity participation?

Yes, to a high degree	◻
Yes, to some degree	◻
No, not at all	◻

5.2. To what extent do you agree or disagree with the following statements?

	Disagree completely	Partially disagree	Neither-nor	Partially agree	Agree completely
I perceive it as safe to bike in my city of residence	◻	◻	◻	◻	◻
I have access to shopping facilities at a walking distance from my dwelling	◻	◻	◻	◻	◻
I prefer to travel by public transport instead of driving whenever possible	◻	◻	◻	◻	◻
I prefer to walk/bike instead of driving whenever possible	◻	◻	◻	◻	◻
I prefer to organize my errands in such a way that minimizes shopping trips	◻	◻	◻	◻	◻
When I go shopping, I usually prefer to do it at the closest store as possible	◻	◻	◻	◻	◻
The streets in my neighborhood are hilly, which makes biking difficult	◻	◻	◻	◻	◻

5.3. How satisfied are you with:

	Highly dissatisfied	Somewhat dissatisfied	Neither -nor	Somewhat satisfied	Highly satisfied
The opportunity to walk to work and other facilities in the city you live in	◻	◻	◻	◻	◻
The opportunity to bike in the city you live in	◻	◻	◻	◻	◻
The public transport service in the city you live in	◻	◻	◻	◻	◻

5.4. To what extent can the following factors get you to walk/bike more that you currently do?

	Highly unlikely	Unlikely	Likely	Highly likely
Residence near city center	◻	◻	◻	◻
Existence of walk/bike paths	◻	◻	◻	◻
Possibility to shower at the trip destination (e.g. at workplace)	◻	◻	◻	◻
Safe walk/bike paths	◻	◻	◻	◻
Lighting on walk/bike paths	◻	◻	◻	◻
Better marking and condition of walk/bike paths	◻	◻	◻	◻
Good maintenance of walk/bike paths	◻	◻	◻	◻
Proximity to bus/train station	◻	◻	◻	◻

Other, please specify: ____

If there is anything else you'd like to tell us regarding your choices about where to live, work, do shopping and leisure activities, and your choices about daily travel, please feel welcome to provide comments below

____

____

____

____

We will draw a lotter worth NOK 6000 among the completed questionnaires.

The winner will be notified via e-mail or telephone. Please write your telephone number or e-mail address:

____

Thank you for participating!

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Norwegian University
of Life Sciences

Postboks 5003
NO-1432 Ås, Norway
+47 67 23 00 00
www.nmbu.no

100648 / ANDVORDGRAFISK.NO