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

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Highlights

- Theoretical premise on the causal mechanism between urban form and travel behaviour in small city context is laid out.
- City-scale built environment factors are strong predictors of average accessibility by active modes in small cities.
- Attitude towards active modes strongly contributes to the propensity for active travel when alternative modes are available.
- Distribution of facilities that optimizes active travel in a small city differs by facility categories.

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 built environment and attitudes influence active travel behaviour in small cities with different centre structures. Using descriptive statistics, ANOVA test and negative binomial regression on survey data, the paper finds that attitude towards active travel as well as accessibility significantly influence walk/bike trip frequency. Moreover, variation in small-city centre structure has an important implication for active travel but the effect varies between facility types.

Previous

Next

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. Active travel refers to trips carried out by self-propelled, physically active means (Cavill, Davis, Cope, & Corner, 2019; Hirst & Dempsey, 2020). Although this definition may include pedelecs and non-motorized scooters, for the purpose of this study, active travel is limited to utilitarian walking and cycling.

The relationship between urban structure and travel behaviour has been one of the most actively researched topics in urban planning during the last three decades. However, the focus has largely been skewed towards 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 the 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 a proxy for local transit accessibility (Bhat & Guo, 2007). The assumption underlying such considerations 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 is small.

Scale (size) limitations constrain small cities from promoting a transit-oriented urban planning that can compete with private car use. Nonetheless, the inherent characteristics of being small do also make these cities ideally suited for active travel which in turn can contribute 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 facilities, personal services and institutional facilities are often concentrated at small-cities' 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 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 3000 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. Any serious effort on sustainable mobility can hence not yield the intended outcome without understanding the mobility dynamics of local travel in these 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 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 are covered in section six followed by the concluding remark.

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. The rational for focusing on non-work trips is twofold: first, work commutes originating from small cities are often long and widely scattered which most of the time is beyond the reach of active modes; second, where home is the trip origin of an active travel, the most frequent purpose of utilitarian travel is to non-work destinations (Millward, Spinney, & Scott, 2013).

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). Positive attitude towards active travel enhances the motivation to walk/bike which again 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, this paper investigates the effect of differences in city-centre structure[3] and the associated distribution of various facilities 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, a combination of which is likely to lead to consolidation of expansionary pressures towards 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. To understand the likely effect of divergent land-use patterns on active travel in a small city context, this article will address the implications of city-scale structural differences and the resulting dispersion of facilities on active travel behaviour.

3. Literature, a critical review

The interest in active travel 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% of all trips are shorter than 3 km (Hjorthol, Engebretsen, & Uteng, 2014). Considering the average walking and cycling distances of 2.2 and 5.5 km 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 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 (Handy, Xing, & Buehler, 2010b; Pucher & Buehler, 2010). Differences within countries are also evident. In Norway, for example, according to the 2013/14 travel survey, active travel accounts for 34% of all trips in the largest four cities while the share is 26% 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 (Handy, Xing, & Buehler, 2010a; 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 in the likelihood as well as magnitude of cycling between Danish municipalities with strong cycling policies and those with less significant policies.

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

The body of knowledge from the last decade or so affirms that built environment influences active travel (Cao, Mokhtarian, & Handy, 2009a; Handy, Cao, & Mokhtarian, 2006; Næss, 2006, Næss, 2014) even after accounting for residential self-selection. Yet, the estimated effect sizes of built environment variables on travel behaviour vary significantly between studies. Travel induced residential self-selection is often the main go-to explanation of such estimate variations, besides other reasons such as spatial scale, the appropriateness of empirical methods and data availability (Crane & Guo, 2012; 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 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, Næss, 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 (Handy, 2005; Handy et al., 2006; Schwanen & Mokhtarian, 2004). 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, Mokhtarian, Handy, 2009a; Pucher & Buehler, 2010). In a small city, 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 (Handy, 2005, Handy, 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, 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 (Ås, 1978; Vilhelmson, 1999).

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 (Handy, 2005).

4. Conceptual framework

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 (Handy, 2010, Handy, 2015). A finding by Cao, Mokhtarian, Handy (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, while 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, city-scale built environment factors (such as city-centre structure and residential distance from the city centre) are also expected to influence active travel by influencing proximity to concentrations of facilities. Fig. 1 illustrates the various factors influencing active travel.

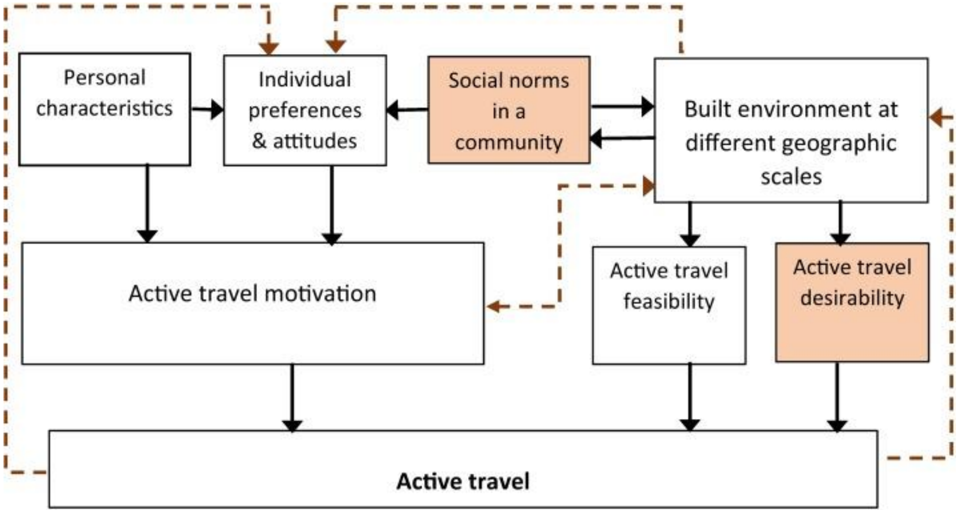

Fig. 1. *Conceptual model of active travel. Adapted from* Handy *(2015).*

Note: Broken lines and light brown boxes indicate causal pathways and variables not considered in this paper. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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 (see Section 3.3). For some facilities, location in neighbourhoods may be optimal 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.

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) (Fig. 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 collectively 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 option. Besides, 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

For active travel, clarity on how attitude, motivation and travel behavioural outcome are linked is critically important. Attitude via its influence on motivation is expected to influence the likelihood of whether at all one chooses 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 option. And without the conducive physical environment for walking/biking there would be no active travel due to the physiological limits (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 (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.

Fig. 2 below presents the distribution of resident's attitudes towards active travel. The histogram shows the relative share of residents with low or high positive attitudes towards active travel at different distance rings around the city centre. It is apparent from Fig. 2 that attitude towards walking/biking is fairly high throughout the urban region.

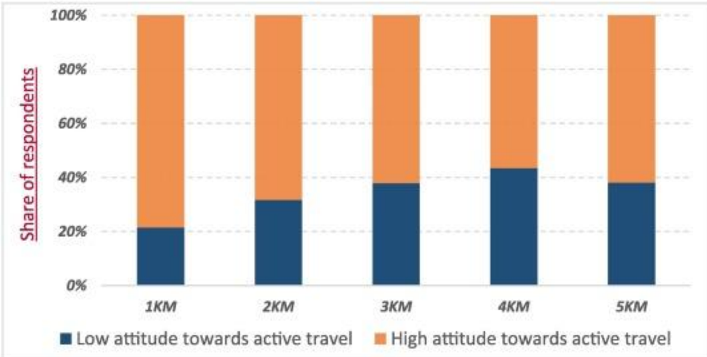

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Fig. 2. Residents' attitudes towards walking/biking at different distance rings from the city centre.

5. Data and method

The study is based on a survey[6] data from 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 (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 the cities of 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	13,405	5.52	2428.4	86%
Jessheim	16,595	6.84	2426.2	51%
Kongsvinger	11,969	7.87	1520.8	67%

Source: (Statistics Norway, 2015).

The three cities differ in the way the city centres are structured. Drøbak has two competing centers. The city market (Torget) is traditionaly considered as the main city center while 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. Fig. A in Appendix A approximates the location of the centres in each city scape.

As shown by Table 2, the sample is fairly representative of the population characteristics. 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.[7]

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

	Kongsvinger (*N*=507)	Municipality of[b] 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≤75 yrs)[a]	52.0	47.3	48.7	43.7	52.0	47.0
Gender (Share of female)[a]	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

a

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

b

The city of Kongsvinger is within the municipality with the same name. The geographic delimitation of the city is limited to the contiguous built-up area. References made to Kongsvinger from here on will specifically refer to the city of Kongsvinger as delimited by the contiguous built-up area unless an explicit mention is made to the municipality.

The survey included indicators for attitude towards walking/biking as well as topography. The attitude indicator was obtained by asking respondents to indicate whether they agreed or disagreed 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 agreed or disagreed 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 is defined as an area within 805 m (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).[8]

To account for the possibility that the effect of accessibility on active travel could vary between facility types, walk/bike trips are categorized into two groups depending, on the one hand on the frequency with which an activity is carried out, and on the other hand on the degree of specialization of the facility. 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 accordance with this grouping, the accessibility indices for the individual facilities are aggregated across facilities to generate average group accessibility.

Another neighbourhood-level 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). Street network connectivity is represented by intersection density measured as the number of intersections in a neighbourhood (805 m radius around the dwelling). The calculation is performed using network analysis in ArcMap. Moreover, 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[9] are also included.

Furthermore, two interaction terms are computed. The first interactions term is computed as the product of attitude and accessibility and represents the interaction between built environment and attitude. The rational for including this interaction term is to assess whether the effect of accessibility also varies by the degree of active travel liking. Controlling for travel attitude without addressing a plausible interaction between BE and attitude would under- or overstate the effect of BE on active travel depending on the sign of the interaction term. 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 in the urban space. 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.

The outcome variable, the number of walk/bike trips to non-work destinations, is a count variable and hence a negative binomial regression[10] 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 means?

In accordance with the research objectives outlined in section two above, I begin the analysis by investigating the effect of built environment on non-work trip frequency for all three cities combined. The dependent variable is weekly trip frequency to non-work destinations. The independent variables included are neighbourhood-level built environment factors (population density, accessibility index, and intersection density), demographics (household size, gender, age mean centred), socio-economic attributes (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 varies by individual heterogeneity in attitude towards active travel. The interaction term turned out to be insignificant and Akaike Information Criterion (AIC), the statistics 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, there is disparity in city-centre structures between the cities where Kongsvinger and Jessheim are monocentric small cities whereas Drøbak is dual centred. Regression analysis on a pulled data with such a disparity ingrained in the data could be sending conflicting signals regarding the effect of the interaction term on the outcome variable which may render the effect of the interaction term indeterminate. Moreover, the effect of accessibility may vary between facility types which further complicates identifying the independent effect of the interaction term. These claims are addressed in detail in Section 6.2 below.

Table 3. Negative binomial regression of active travel covariates.

	Coefficient	P-value	Elasticity
Intersection density	0.00129	0.000	0.34607
Walk/Bike attitude	0.27762	0.000	0.95739
Accessibility to facilities	0.00797	0.000	0.06662
Employment	−0.32212	0.000	−0.23076
Car access	−0.63743	0.000	−0.61260
Topography	−0.05907	0.002	−0.13600
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.

Employment, access to car and topography[11] 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 in small cities, for example, through awareness campaigns (Barnes et al., 2013).

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 neighbourhoods as the edge of the small cities is within 3–6km 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	−0.2979 (0.002)	−0.4903	−0.3463 (0.000)	−0.7148	−0.0480 (0.301)	−0.0907
Walk/Bike attitude	0.3273 (0.000)	1.1820	0.2292 (0.000)	0.7956	0.2470 (0.000)	0.8294
Accessibility to facilities	0.0022 (0.616)	0.0138	0.0016 (0.299)	0.0161	0.0146 (0.000)	0.1244
Employment	−0.4585 (0.000)	−0.3015	−0.2286 (0.016)	−0.1721	−0.3332 (0.000)	−0.2396
Car access	−0.5506 (0.006)	−0.5294	−0.5562 (0.000)	−0.5370	−0.6561 (0.000)	−0.6292
Topography	−0.1191 (0.006)	−0.2928	0.0208 (0.707)	0.0291	−0.0640 (0.028)	−0.1852
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 into 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.

Results reported in Table 4 highlight two noteworthy findings that are especially pertinent to small-city contexts. Based on these findings, a few relevant points can be highlighted both in contrast to larger cities and in regard to factors leading to heterogeneous outcomes among smaller cities. First, residential distance from the city center (a city-scale variable) is an important measure of average accessibility by active modes. This is one of the strengths of small cities vis-à-vis larger cities. The compact nature and size of smaller cities makes various destinations in the cityscape reachable by active means, which opens for the plausibility of integrating active modes as city-scale mobility solution in transportation planning for smaller cities. In contrast, the same variable is primarily associated with motorized transport in larger cities (Ding, Cao, & Næss, 2018). Using mixed methods research, Næss, 2005, Næss, 2013 consistently shows that daily traveling distances tend to be more influenced by the distance from the dwelling to the city's main concentration of facilities (usually the inner city) than by its distance to local centers. In larger cities, these destinations are largely beyond what is physiologically reachable distance by slow travel modes. Second, the configuration, that is the compact vs diffused nature of the city center has important implication for the extent of active travel in a small city. This part is discussed in more detail in the following section (Section 6.2 and onwards).

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

Lumping up walk/bike trips to various facilities into one active travel variable, as in Table 3, Table 4, depicts the general trend of the covariates. But, because the effect of accessibility is likely to vary between facility types, such aggregate methods may lose certain important nuances. To capture a more nuanced effect of accessibility on active travel, the facility types are categorized into two groups: neighbourhood facilities (grocery stores) and centre facilities (cafés, restaurants, medical clinics and facilities for errands other than grocery stores). Fig. 3, Fig. 4 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.

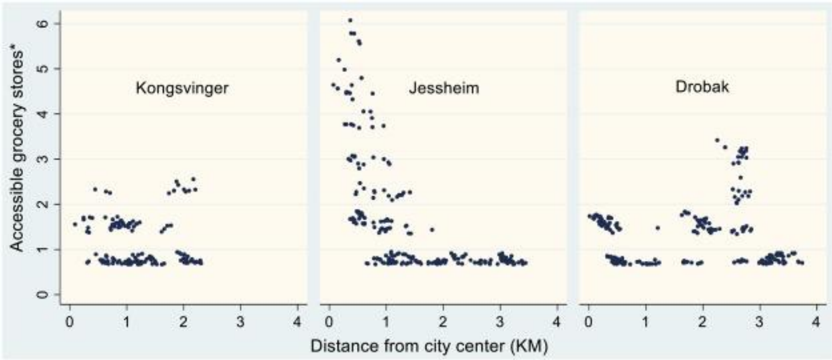

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Fig. 3. Accessibility distribution to grocery stores from city centres of the respective cities

*Number of grocery stores that can be accessed within 850-meter range from a residence

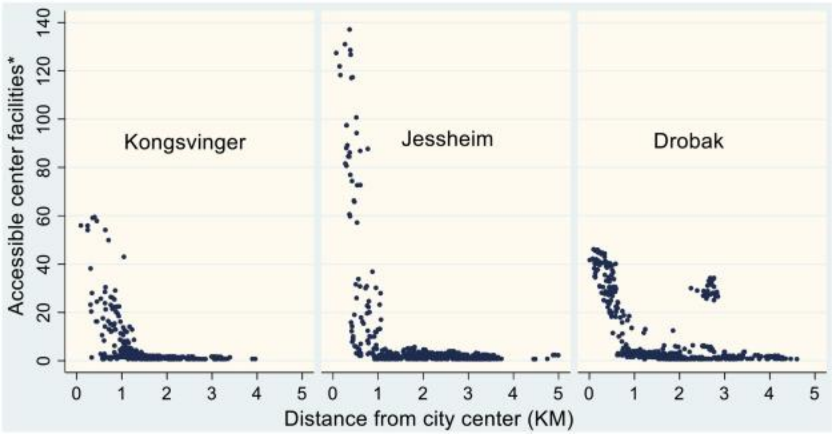

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Fig. 4. Distribution of accessibility to centre facilities in the cityscapes.

*Number of center facilities that can be accessed within 850-meter range from a residence

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 substantial proportion of grocery stores are concentrated at the city centre.

The distributional pattern of 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 in two locations: one at the city centre and the other at a shopping centre in the outskirt of the city.

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 modelled for a sub-sample where accessibility is greater than zero.[12]

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 in Table 5 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 in Drøbak. This is likely because some of the main grocery stores are clustered at the shopping centre at the fringe of Drøbak city (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, which is indicative of the highly centralized location of centre facilities in Jessheim.

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 category: 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-economic, attitudinal factors and an interaction term between accessibility and the measure of facility dispersion. Variables that are significant at a 5% 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 grocery facilities leads to lower propensity of active travel. 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.

From the remaining built environment attributes specified in the model for grocery stores, the accessibility index has the strongest influence on trip frequencies to grocery stores and corresponds with previous findings (Ewing & Cervero, 2010). Although the interaction term is negative and somewhat reduces the overall 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. Dispersion of center facilities (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 facility dispersion 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.

Consistent with the findings in Table 3, Table 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.

6.3. Limitations

This study has a few 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, and that walking tends to substitute cycling for trip distances below 500 m (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.

However, it should be recognized that 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% 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 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.

7. Conclusion

Small cities are largely overlooked in studies investigating the built environment – travel behaviour nexus. By casting the limelight on small cities, this paper contributes to the existing literature in several way. Through a critical review of literature, the paper laid out the theoretical and conceptual foundation as a precursor for an appropriate model specification to the empirical analysis in the case of small cities. The theoretical foundation laid out in this study and the empirical findings affirm that difference in city size has important implications on whether and how the causal tendencies (Bhaskar, 2008) between built environment and travel behaviour are manifested, and the role of attitude in this relationship. Although the general tendency is similar to that of larger cities in that centralization and compact development fosters sustainable mobility as Tennøy, Gundersen, and Øksenholt (2022) have also confirmed, there are a few nuances that need to be highlighted in the cases of smaller cities. Residential distance from the city center and city center structure are cases in point. Both variables are city-scale built environment factors that are primarily associated with motorized transport in larger cities. Conversely, these same variables are important measure of average accessibility by active modes in the context of small cities.

For small cities (in the size range studied here) the average residential distance to the city center is short enough for the city center to be accessible by active modes from almost all locations. In this respect small cities have resemblance to the concept of “the 15 minute neighbourhood” (Moreno, Allam, Chabaud, Gall, & Pratlong, 2021; Sutcliffe, 2020) used as an organizing principle in creating sustainable neighbourhoods in large cities. The important distinction here is that a neighbourhood in larger cities is one of many units with the potential for integrated city-scale transit service whereas small cities are mostly self-contained and independent units specially for non-work trips and where efficient transit service is inadequate. The city-scale accessibility by active modes and the limited constrained access elevates active travel to viable city-scale mobility solution in transportation planning for smaller cities.

The small city's internal layout in terms of city center structure and distribution of facilities are important nuances urban planners should take into consideration to optimize active transport use. Small city residents with high accessibility of grocery stores in their neighbourhood are highly likely to walk/bike for errands. For centre facilities on the other hand centralization (concentration of facilities at the city centre) is more strongly associated with higher walk/bike frequency. Meaning, a concentration of center facilities at the center of a small city offers higher average accessibility to a range of these facilities and hence likelihood utilitarian active travel to these facilities than when these facilities are spread around.

This research clearly demonstrates that facility distribution has significant effect on the propensity to use active modes in small cities. 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 revealed that attitude towards active travel to exert the strongest influence on the propensity to bike/walk. This finding has an important implication for smaller cities because smaller cities are largely car dependent, and the decision to commit oneself to walk or bike when alternative means of transport is available depends largely on the motivation to do so. 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.

Author statement

This paper is an original research work and has not been submitted or published earlier in any journal and is not being considered for publication elsewhere.

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Credit author statement

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Declaration of competing interest

The authors declare that no competing interests are at stake and there is no conflict of interest with other people or organizations that could inappropriately influence or bias the content of the paper.

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Appendix A.

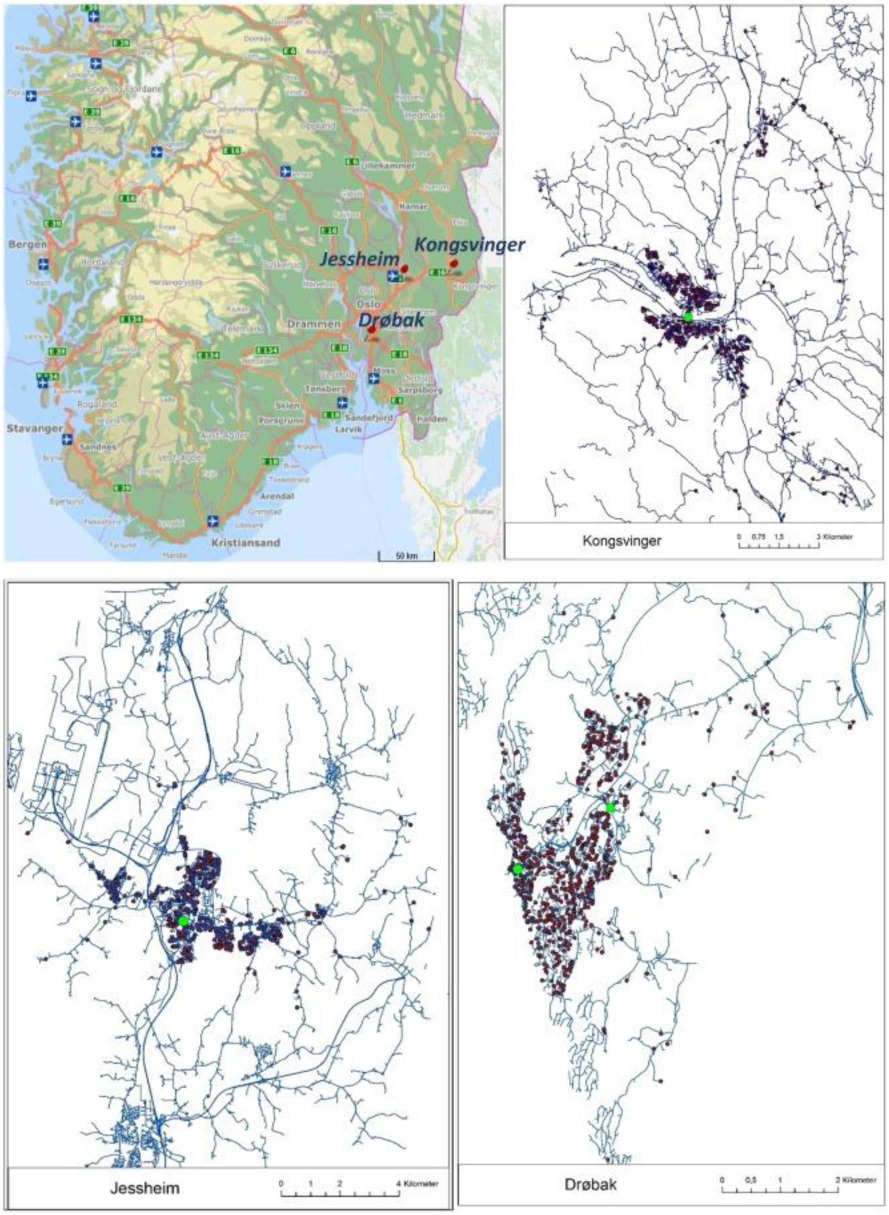

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Fig. A. Map of southern part of Norway and street network map of the case cities.

Note: The green dots represent city centres and the red dots represent residential units in the sample.

Recommended articles

Data availability

Data will be made available on request.

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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

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 m. Deviations are allowed when there are natural barriers such as rivers or arable land and land developments such as e parks, sports facilities and industrial areas disrupting continuous development. In which case agglomerations that naturally belong to the urban settlement with up to a distance of 400 m from the center of the urban settlement are also included.

3 City-center structure, as used in this paper, is a city-scale characterization and 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, Strand, Wolday, & Stefansdottir, 2017).

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

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

6 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 6000 NOK (approx. USD 750).

7 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.

8 $A_{ij} = \sum_j W_{ij} e^{-C_{ij}}$ - 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 trips to fitness facilities.

9 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 transport. 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.

10 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.

11 Topography refers to the difficulty of biking due to hilly streets in the neighbourhood.

12 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. The sub-sample in this section of the analysis includes only those residences with positive values in the accessibility index.