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Shifting towards active and sustainable commuting: the relative importance of factors associated with reduced car commuting among Finnish public sector employees

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ABSTRACT

Shifting from car to walking, cycling, or public transport increases physical activity and decreases traffic-related emissions. However, many commutes with healthier transportation options are still undertaken by private cars, highlighting the need for a deeper understanding of the factors associated with commuting modal shift. By linking individual-level survey data with grid-based data on the residential environment, we examined the relative importance of factors associated with reduced car commuting from 2020 to 2022 among 4464 Finnish public sector employees using dominance analysis. While the overall predictive power of the analysis was low, shorter average commute length, lower proportion of green areas, being a non-smoker, higher proportion of households without a car, shorter distance to the nearest grocery shop, less car ownership, higher total physical activity, and lower body mass index emerged as the most important factors. Results suggest that residential environment, health, and health behaviours only explain a small proportion of the total variance in a shift towards healthier commuting. Future studies should explore the role of individual psychosocial factors and workplace environment characteristics in explaining modal shifts in commuting within Nordic countries.

1. Introduction

Physical activity promotion and climate change mitigation are globally recognised as core public health priorities (Guthold et al., 2018; Katzmarzyk et al., 2021; World Health Organization, 2020). Shifting from car commuting to walking, cycling, and public transport use is a viable strategy to increase habitual physical activity and reduce carbon emissions, air pollution, and noise from motorised traffic, especially within urban areas (World Health Organization, 2022; Giles-Corti et al., 2016; Xiao et al., 2019; Rissel et al., 2012). However, many walkable and cyclable commuting trips – including those with a plausible public transport option – are undertaken by private cars (Fiorello et al., 2016; Paul et al., 2013). In Finland, for example, recent estimates suggest that 30 % of car commutes could be replaced by active and sustainable transportation modes (Traficom, 2023). Therefore, it is essential to better understand the factors associated with a modal shift to accelerate the change towards more physically active and environmentally friendly commuting.

Previous studies, mainly from Europe, North America, and Australia, have found that various individual and environmental factors are

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positively associated with transport-related physical activity. For example, adults with lower socioeconomic status, higher self-efficacy, and/or more positive beliefs about the physical activity consequences are more likely to engage in active travel (Garcia et al., 2022; Evans et al., 2022). Regarding environmental factors, better walkability, shorter travel distances, and higher destination concentrations seem to predict higher levels of walking and cycling (Garcia et al., 2022; Evans et al., 2022).

Factors associated with public transport use are somewhat different. For example, two European studies using social-ecological approaches observed that women and students, as well as those with higher education, living in high-density areas, and valuing lower travel times or costs, use trains, trams, underground, and buses more frequently (Gascon et al., 2020), although some regional differences exist (De Witte et al., 2013). Nevertheless, a key limitation in prior research is that fewer studies have assessed the factors associated with an actual modal shift from private car use towards more active and sustainable commuting. This gap is particularly evident in Nordic countries, where unique cultural, geographical, and climatic environments may influence commuting behaviours.

The relative importance of factors associated with such modal shifts is also underexplored. For example, an Italian study found that bicycle use habits, financial incentives, and attitudes were stronger predictors of cycling intentions than, for example, social norms and perceived behavioural control (Baeli et al., 2022). Expanding this research area and identifying the most important predictors of reduced car commuting could help public health practitioners and city planners to design sustainable urban environments, effective interventions, and, consequently, healthier, more physically active cities (Giles-Corti et al., 2022).

We conducted a data-driven exploratory study in which we examined the relative importance of sociodemographic factors, health status indicators, health behaviours, work-related factors, and residential environment characteristics for reduced car commuting among Finnish public sector employees.

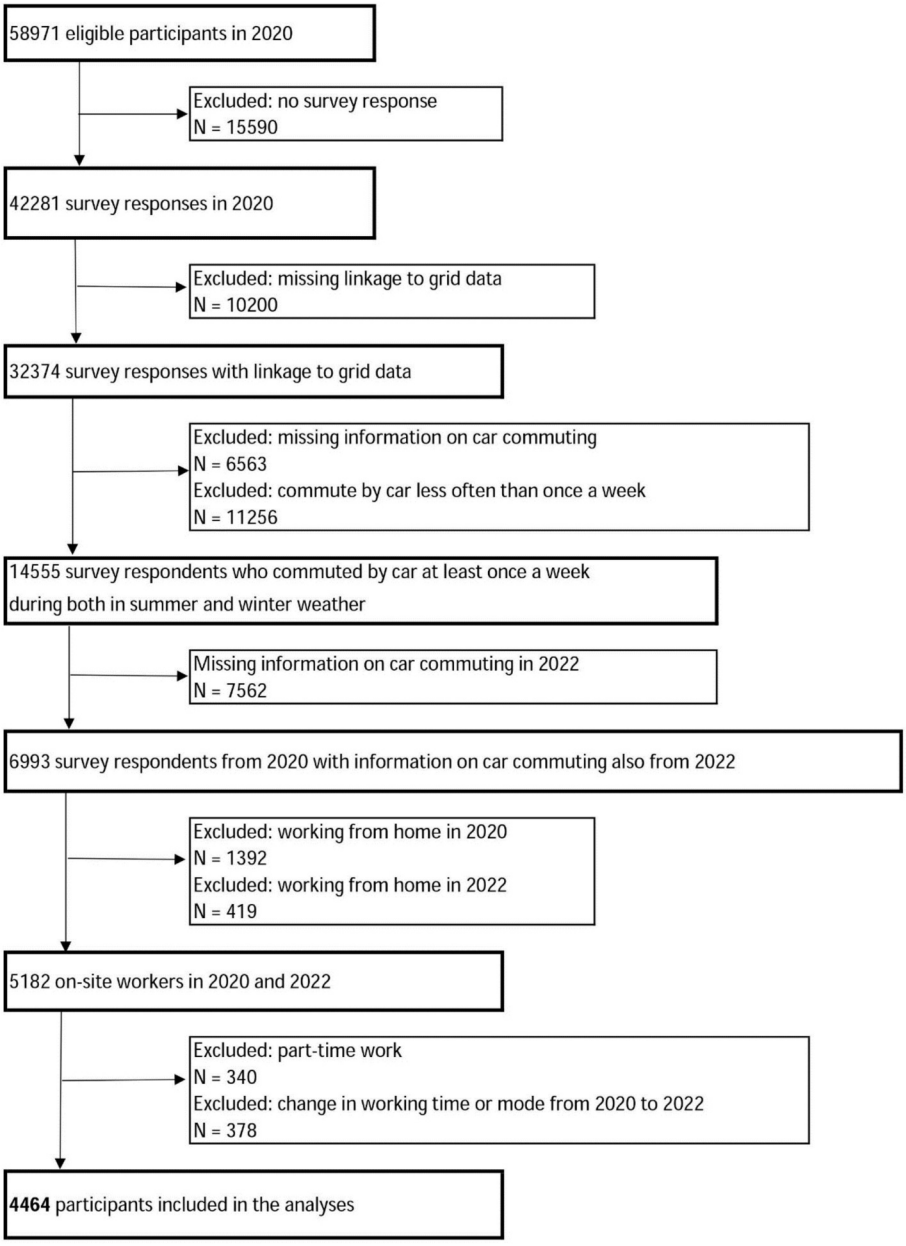

Fig. 1. Flow chart of the sample selection.

2. Methods

2.1. Data and participants

This study was based on a subsample of the Finnish Public Sector (FPS) study (Finnish Institute of Occupational Health, 2024; Ervasti et al., 2021), including four cities with questions on commuting behaviour on employee surveys in 2020 and 2022. Survey responses were linked to grid-based data on residential environment characteristics provided by the Finnish Environment Institute. Ethical approval for the FPS study was granted by the Helsinki and Uusimaa Hospital District Regional Committee on Medical Research Ethics (HUS/1210/2016).

In the autumn of 2020, the survey was sent to 58,971 employees of the four cities. Of those, 42,281 responded (response rate 72 %). We included survey respondents who commuted by car at least once a week both in the summer and winter in 2020 and had data on car commuting from the 2022 survey (N = 6993). From those, we included full-time on-site workers whose work schedule (working hours or shifts) did not change from 2020 to 2022, as changes in working from home, part-time work, and working time may affect the frequency of car commuting. Thus, the final analytical sample comprised 4464 participants. The sample selection is detailed in Fig. 1.

2.2. Measures

2.2.1. Reduction in car commuting from 2020 to 2022

We asked the survey respondents to evaluate how often they commuted by car separately in summer and winter conditions. Response categories were: 1 = daily or almost daily; 2 = a few times a week; 3 = once a week; 4 = less than once a week; 5 = never. The responses were recoded into days per five-day workweek as follows: daily or almost daily = 5; a few times a week = 3; once a week = 1; less than once a week = 0.5; and never = 0. Car commuting scores from summer and winter were summed and then divided by two to achieve a year-round weekly car commuting average. Reduction in commuting by car (yes/no) was determined by subtracting the 2020 commute score (range 1–5) from the 2022 commute score (range 0–5), with positive values indicating a reduction in car use. As the participants were on-site workers whose working time did not change, reduced car commuting implied increased active commuting or public transport use. While the data did not distinguish between intra-city and inter-city commuting, it is likely that most commutes occurred within the cities.

2.2.2. Predictor variables

We did not preselect predictor variables but utilised a total of 55 potential individual-level predictors of reduced car commuting available from the 2020 FPS study data, including participants' sociodemographic characteristics (e.g., age and sex), psychosocial work characteristics (e.g., job demands and team climate), other work characteristics (e.g., individual commute length and worktime control), health status indicators (e.g., self-rated health and body mass index), and health behaviours (e.g., smoking status and alcohol use).

Participants' addresses were obtained from the Digital and Population Data Services Agency in 2020. The residential environment was characterised using a grid database containing coordinate-based data from 2020. This data describes residential neighbourhood characteristics within 250 × 250 m grid cells with 15 measures: location within urban structure (distance to city centre or subcentre and travel-related urban zone), availability of services (number of jobs in hotels, restaurants, and cafés), distance to a school, distance to a grocery shop, and distance to a large grocery shop), population and job density, the proportion of green areas, the proportion of owner-occupied dwelling units, average household size, car ownership (proportion of carless households and the most common car-ownership type), average commute length, and sociodemographic characteristics (average household income and proportion of people speaking foreign languages). The measures describe either the grid cell, that is, the area where the respondent lives (e.g., in accessibility measures) or the average of cells within one kilometre of the respondents' home location (e.g., in sociodemographic characteristics). The survey respondents' residential addresses were linked to the grid database using coordinate data (EUREF-FIN). Workplace addresses were not available, which prevented us from examining the characteristics of the full commute route from home to work.

The chosen data-driven approach allows for a more comprehensive assessment of potential factors influencing modal shift than traditional analyses using single predictors from a single source.

A detailed description of all predictor variables is provided in the supplementary material.

2.3. Statistical analysis

First, we performed a multiple imputation with one imputed dataset on missing data using the R package *mice* (see Fig. S1 for more information about the missing data). Next, we examined bivariate associations between each predictor variable and reduction in car commuting (yes/no). Wilcoxon rank sum test and Chi-squared test were used for continuous and categorical variables, respectively. Predictor variables that showed a significant Bonferroni-corrected association with reduced car commuting were selected for the main analysis. These variables demonstrated adequate heterogeneity (see Table S1 for variances and standard deviations).

In the main analysis, we used dominance analysis (type = general dominance) with logistic regression to examine the relative importance of the variables predicting a reduction in car commuting. Dominance analysis can be used to determine which predictors are the most important regarding their proportional contribution to the explained variance in an outcome (i.e., their predictive power) (Azen and Budescu, 2006). While interpreting regression coefficients in traditional multiple regression may lead to misleading conclusions when predictors are correlated (Johnson and Lebreton, 2004), dominance analysis is robust in the face of multicollinearity. The method calculates the change in the explained variance by adding each predictor to all possible regression models and then averages these changes across all models for each predictor.

Regarding logistic regression, where the outcome is dichotomous, the predictive power of the dominance analysis can be assessed using McFadden's pseudo-R-squared metric (Azen and Traxel, 2009). Although the pseudo-R-squared does not have the same intuitive meaning as R-squared in linear regression, it provides a measure of the proportion of variance explained by the logistic regression model. The pseudo-R-squared ranges from 0 to 1 with higher values indicating better predictive power. Additionally, we report the Akaike information criterion (AIC) and log-likelihood estimates with results from likelihood-ratio test from null model (all variables) and final model (variables significantly associated with reduced car commuting).

As a sensitivity analysis, we performed a stratified dominance analysis for commuting distances of five kilometres or less and more than five kilometres. This choice was based on two assumptions: 1) commuting distances less than five kilometres are cyclable and – to some degree – walkable (Goel et al., 2021); and 2) the relative importance of different predictors may differ when the number of alternative options for car use changes (Garcia et al., 2022; Evans et al., 2022; Gascon et al., 2020; De Witte et al., 2013). For example, public transport may be the only viable alternative for car when distance is longer than five kilometres.

Data management, including imputation and visualisations, were performed using R (4.3.0). All statistical analyses were performed using Stata (version 18).

3. Results

Most participants were women (77 %), and the mean age of the

participants was 48 years (SD = 9, range 21–67). On average, the length of their one-way commute was 15 km (SD = 16, range 0.3–250). A total of 1018 participants (23 %) reported reduction in car commuting from 2020 to 2022.

3.1. Bivariate associations between predictors and reduced car commuting

Fig. 2 shows the bivariate associations between all predictor variables and the reduction in car commuting. Most notably, variables related to the residential environment, health status, and health behaviours showed associations with the outcome. After Bonferroni correction, a total of 17 predictors were significantly associated with reduced car commuting. The bivariate associations for these 17 variables and the outcome are shown in Table 1.

In the sensitivity analyses, we did not observe any Bonferroni-corrected associations between the predictors and reduced car commuting for distances of five kilometres or less. For distances of more than five kilometres, 18 predictors were associated with the outcome (Table S2).

3.2. Relative importance of predictors of reduced car commuting

The dominance analysis with 17 predictor variables involved running a total of 131,071 logistic regression models. The McFadden pseudo-R-squared, measuring the overall predictive power of the dominance analysis, was 0.039 (3.9 %). For the null model, the AIC value was 4795.5 and log-likelihood estimate was −2396.7. Indicating better fit, the AIC value decreased to 4639.9, and log-likelihood increased to −2301.9 in the final model (likelihood-ratio test < 0.0001). The most important predictors of reduced car commuting were shorter average commute length within the residential area (15 % of the explained variance), lower proportion of green areas within the residential area (12 %; typical for areas that support public transport services), being a non-smoker (11 %), higher proportion of households without a car within the residential area (10 %), shorter distance to the nearest grocery shop within the residential area (8 %), less car ownership within the residential area (7 %), higher total physical activity level (6 %), and lower body mass index (5 %). The relative importance of all predictors is presented in Fig. 3 (see Table S3 for more details).

In the sensitivity analysis, the McFadden pseudo-R-squared was 0.054 (5.4 %) for commutes of more than five kilometres (Table S4). The most important predictors were mainly the same as in the main analysis, although also two work-related factors, better worktime control (10 %) and shorter employment duration (5 %), emerged.

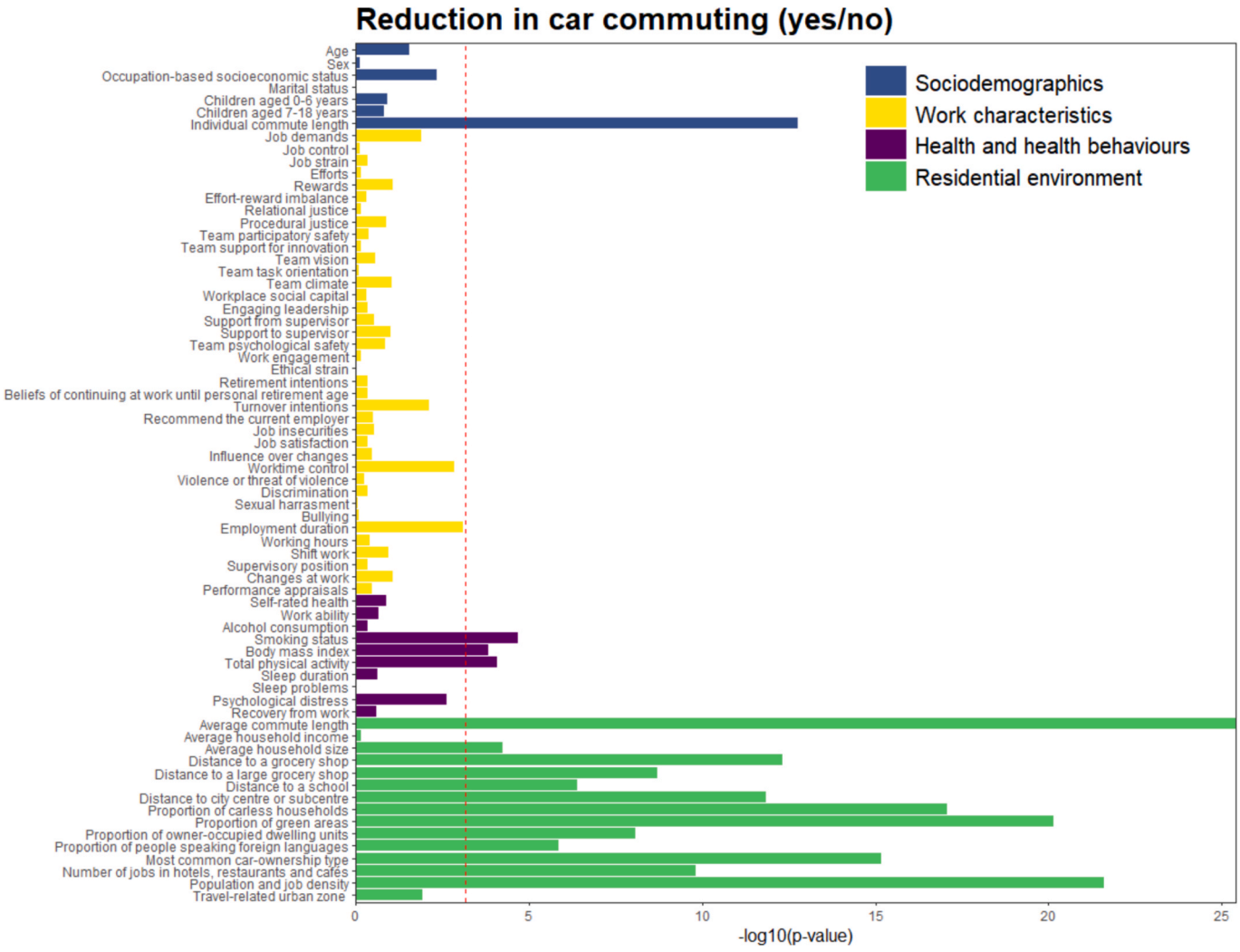

Fig. 2. Bivariate associations between variables and reduction in car commuting. The red dashed line indicates Bonferroni-corrected statistical significance at P < 0.05/70.

Table 1
Descriptive statistics of the statistically significant predictors of reduced car commuting by reduction status and in order of importance. Figures are means with standard deviation (SD) for continuous variables and frequencies with percentage (%) for categorical variables.

Predictor	No reduction in car commuting (N = 3446)	Reduction in car commuting (N = 1018)
Average commute length, kilometres	13.7 (4.7)	12.2 (3.9)
Proportion of green areas, %	43 (20)	37 (17)
Smoking status		
Non-smoker or ex-smoker	3023 (88 %)	941 (92 %)
Current smoker	423 (12 %)	77 (8 %)
Proportion of carless households, %	32 (17)	37 (16)
Distance to a grocery shop, meters	919 (1,250)	617 (736)
Most common car-ownership type		
No car	1117 (32 %)	455 (45 %)
One car	1762 (51 %)	475 (47 %)
Two or more cars	567 (16 %)	88 (8.6 %)
Total physical activity, weekly MET-hours	4.8 (4.0)	5.4 (4.3)
Body mass index	27.3 (5.2)	26.6 (4.8)
Average household size, persons	2.12 (0.37)	2.07 (0.34)
Distance to city centre or subcentre, kilometres	2.2 (2.6)	1.6 (1.9)
Population and job density	3831 (3930)	4825 (4330)
Distance to a large grocery shop, meters	1907 (2647)	1343 (1725)
Individual commute length, kilometres	15 (16)	12 (14)
Proportion of owner-occupied dwelling units, %	55 (17)	51 (16)
Distance to a school, meters	899 (950)	724 (691)
Proportion of people speaking foreign languages, %	16 (10)	17 (10)
Number of jobs in hotels, restaurants, and cafés	103 (254)	123 (270)

4. Discussion

We examined the relative importance of individual and environmental factors associated with reduced car commuting among Finnish public sector employees. Factors related to residential environment, commute length, health status, and health behaviours had the strongest associations; however, the total predictive power of these factors was low. For commutes longer than five kilometres, better worktime control and shorter employment duration also emerged as explanatory factors.

Our observations on residential environment and commute length align with prior, predominantly cross-sectional research, including a recent study from the same FPS cohort (Garcia et al., 2022; Evans et al., 2022; Gascon et al., 2020; De Witte et al., 2013; Makkonen et al., 2024). However, a few longitudinal studies and natural experiments have also reported associations between built environment and active commuting or public transport use (Kärmeniemi et al., 2018). For example, a longitudinal study from the UK showed that those who lived further away from work were less likely to increase active commuting (Yang et al., 2017). Moreover, adults living in areas with a higher density of employment locations tended to maintain their walking and cycling levels (Yang et al., 2017). Similarly, also in the UK, proximity to busway and higher convenience of public transport predicted an increase of commuting trips involving active travel and a decrease of trips made exclusively by car (Heinen et al., 2015; Panter et al., 2014). Regarding Nordic countries, greater proportion of green spaces have been associated with higher levels of active travel on non-working days and after retirement, but not on workdays, among late middle-aged Finnish adults (Pasanen et al., 2024). In our study, the average commute length likely describes the quality of walking and cycling infrastructure, as well as the availability of public transport services within the residential area, while individual commute length directly indicates the actual commute distance.

While an environment that promotes the use of active transportation modes has been consistently associated with reduced car commuting and increased walking, cycling, and public transport use, the magnitude of the effects is somewhat unclear. For example, a recent review found that infrastructural changes (e.g., implementation of parallel walking and bicycle trails and bus lanes) may increase cycling, but not walking or total physical activity (Stappers et al., 2018). Indeed, some evidence suggests that in countries where cycling infrastructure is already well-developed, individual-level factors may be more important predictors of active commuting (Logan et al., 2023). For example, a study from Belgium found that social support, self-efficacy, and perceived benefits were better predictors of cycling than environmental factors (de Geus et al., 2007). Similarly, in the Netherlands, living closer to work, health benefits of cycling, and getting enough exercise were considered more important than, for example, accessibility of work location and attractiveness of the routes (Engbers and Hendriksen, 2010). This might also apply to Finland, where walking, cycling and public transport infrastructure is extensive and accessible to a vast majority of Finns (Tilastokeskus, 2023), potentially explaining the low overall predictive power of residential environment and commute length in our study. Alternatively, despite the relatively good coverage of public transport services and walking and cycling infrastructure in large Finnish cities, private car is on average the fastest transport mode (Traficom, 2023), which may reflect a certain path dependency in car use.

Of individual-level factors, we found that being a non-smoker, higher total physical activity, lower body mass index, and, for distances of five kilometres or more, better worktime control were associated with reduced car commuting. These factors correspond with a previous cross-sectional study on factors associated with commuting behaviour among Finnish public sector employees (Makkonen et al., 2024). In studies conducted elsewhere, physical activity attitudes and behaviours have also been linked to higher levels of transport-related walking and cycling (Evans et al., 2022). This suggests that adults with higher total physical activity levels may also have greater self-efficacy for active commuting (Bopp et al., 2014; Simons et al., 2017), and that they enjoy and prioritise using healthier transportation modes (Bopp et al., 2019; Thern and Sjögren Forss, 2014). Regarding body mass index, the evidence is mixed, although some studies suggest that overweight or obese individuals tend to engage less in transport-related physical activity (Evans et al., 2022). Additionally, better worktime control, such as being able to affect the length and timing of work hours, may facilitate a more flexible daily commuting schedule. This flexibility may enable individuals to use scheduled public transport, for example, which is generally more time consuming than private car use (Liao et al., 2020).

The strengths of this study include a large cohort of Finnish public sector employees across different occupations. We were able to use a wide set of potential factors associated with reduced car commuting, including grid-based characteristics of residential environment, and more rarely studied factors such as psychosocial work environment. Linking survey data with grid-based data also reduces the likelihood of common source bias. Our study strengthens the existing evidence by evaluating the relative importance of factors associated with (at least) a gradual modal shift towards more active and sustainable commuting. Moreover, our study design, where the outcome variable was based on a reduction in car commuting instead of prevalence on car commute, provides further evidence that shorter commutes and residential environment that promotes walking, cycling, and public transport use may – to some extent – reduce car commuting (Prince et al., 2023). In addition to urban commuting in Nordic countries, these findings may be generalisable at least to other medium-sized European cities that share similar commuting behaviours and built environment characteristics. However, given the unique climatic conditions (e.g., long winters) of

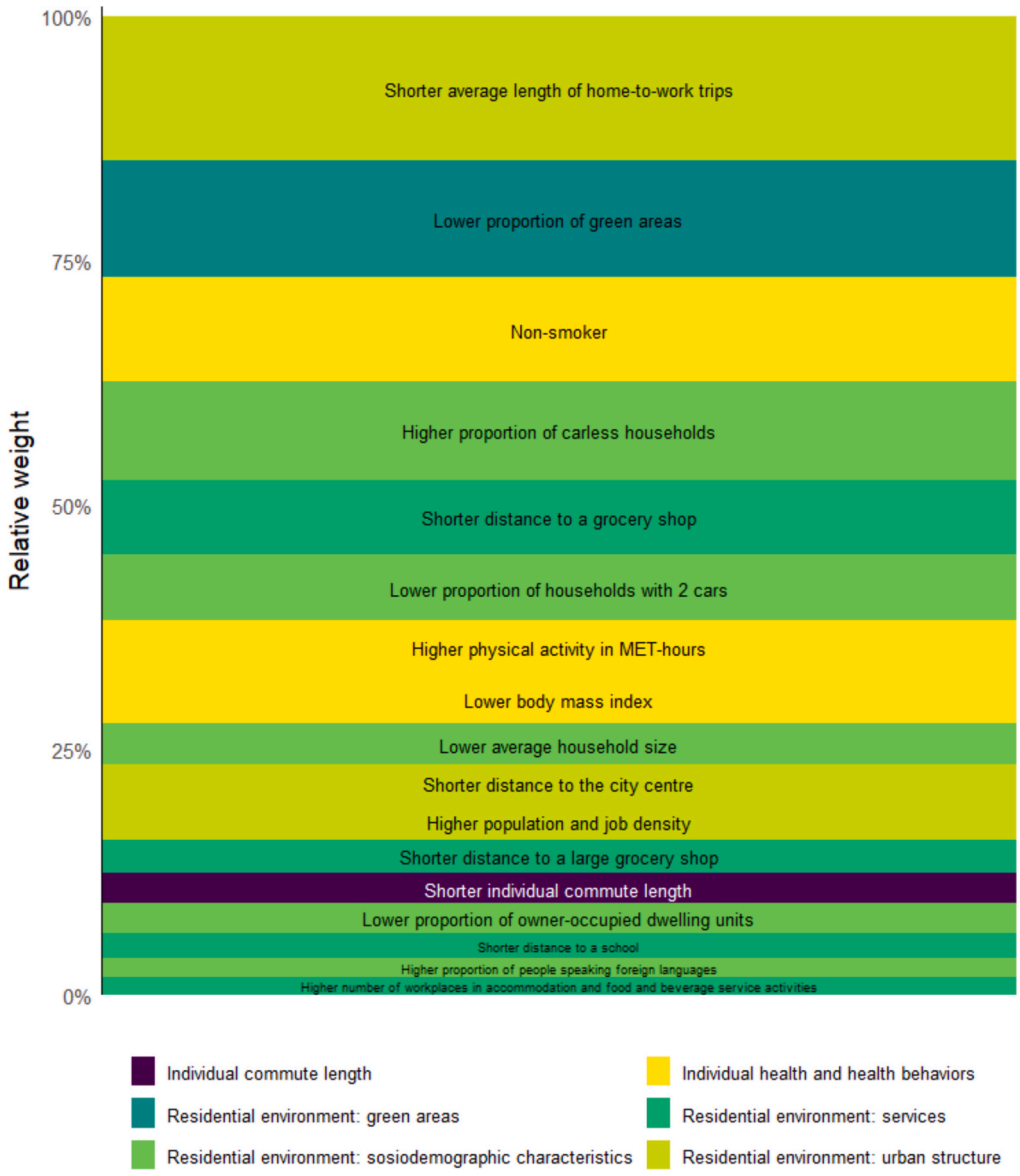

Fig. 3. Predictive power of the statistically significant predictors and their relative importance on reduced car commuting. The overall predictive power of these factors was 3.9%.

Northern Europe, we encourage future research to examine the relative importance of these and other factors across different cities to strengthen the theoretical understanding and build upon our observations.

Our study also has limitations. As in the Finnish public sector in general, most participants were women. Thus, in addition to private sector employees, our observations may not be generalisable to men, who use private cars more frequently than women (Tiikkaja and Liimatainen, 2021; Traficom, 2023). Furthermore, although the FPS study comprises public sector employees of various occupations (e.g., teachers, health and social care workers, office workers, construction workers, and transportation workers), the proportion of participants with low socioeconomic status is relatively small (Ervasti et al., 2021), limiting the generalisability to employees in low socioeconomic position.

We were also not able to differentiate whether car commuting was replaced with walking, cycling, or public transport use, which limits the applicability of the results to interventions focused on promoting specific alternative commute modes. For commutes longer than five kilometres, where the main alternative commute mode is public transport, the predictors and their relative importance were similar to those in the main analysis. For walkable and cyclable commuting distances (five kilometres or less), we did not find any significant predictors. However, this was likely due to the low number of observations in this subgroup, and, subsequently, lack of statistical power.

Moreover, although we were able to include numerous potential predictors, we did not have information on self-efficacy, social support, and perceived benefits related to active commuting. These types of psychosocial factors have been previously associated with transport-related physical activity (Garcia et al., 2022; Evans et al., 2022; de Geus et al., 2007; Engbers and Hendriksen, 2010; Bopp et al., 2014; Simons et al., 2017; Bopp et al., 2019; Thern and Sjögren Forss, 2014). We also could not control for residential self-selection. It is possible that some individuals may choose to live in areas conducive to active commuting based on their existing preferences or constraints, which could have biased our findings. Future studies should also aim to include explicit questions or controls to enable separation of the two pathways via which built environment characteristics may be associated with commuting mode: residential location preferences or later change of behaviour due to the features of the area. Finally, while our study

provides valuable new insights into the determinants of reduced car commuting over a two-year follow-up period, its observational design limits the ability to draw causal inferences.

The observed reduction in car commuting between 2020 and 2022 can also be partly explained by the mobility changes caused by the COVID-19 pandemic. For example, the environmental factors that were associated with reduced car commuting typically describe dense urban areas that support public transport services (e.g., lower proportion of green areas). Therefore, the recovery of public transport use after the first year of the pandemic can contribute to the reduced car use. Despite this, the analysis reveals factors that support modal shift also in the post-pandemic era. Additionally, our analysis included only individuals who worked on-site throughout the study period and whose work schedules (working hours or shifts) remained unchanged. Therefore, pandemic-related disruptions are unlikely to have a major impact on our observations.

Regarding urban mobility policymaking, our observations suggest that central urban areas with short commute distances have some potential in reducing car commuting. At individual level, also health and health behaviours may have a role in such modal shift. However, future studies should examine additional predictors – such as psychosocial factors related to personality and private life, but also infrastructural factors along the full commute route, including traffic jams, parking availability, and parking fees near workplace. This would help to gain a more comprehensive understanding of the conditions under which people are willing to reduce car commuting. Furthermore, future research should explore whether promoting walking, cycling, or public transport use could also have unintended consequences, for example, reduced job accessibility due to increased commuting time.

To the best of our knowledge, this was the first data-driven longitudinal study to examine the relative importance of factors associated with reduced car commuting in Northern Europe. In conclusion, residential environment that promotes the use of alternative commuting modes, shorter commute length as well as better health status and health behaviours was associated with a modal shift towards more active and sustainable commuting in Finland. However, most of the variance in reduced car commuting was left unexplained, highlighting the complexity of predicting shifts in commuting modes.

5. Data statement

Data are available upon reasonable request. The deidentified data and statistical analysis code that support the findings of this study are available on reasonable request from JE. The data are not publicly available due to legislative restrictions, as the data contains information that could compromise the privacy of the research participants.

CRediT authorship contribution statement

Juuso J. Jussila: Writing – original draft, Project administration, Methodology, Conceptualization. **Kia Gluschkoff:** Writing – review & editing, Methodology, Formal analysis, Data curation, Conceptualization. **Jaana I. Halonen:** Writing – review & editing, Conceptualization. **Olli Kurkela:** Writing – review & editing, Visualization. **Timo Lanki:** Writing – review & editing, Conceptualization. **Anna Makkonen:** Writing – review & editing, Conceptualization. **Antti Rehunen:** Writing – review & editing, Resources, Data curation, Conceptualization. **Paula Salo:** Writing – review & editing, Conceptualization. **Emilia Suomalainen:** Writing – review & editing, Conceptualization. **Marko Tainio:** Writing – review & editing, Conceptualization. **Jenni Ervasti:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tbs.2025.101154.

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