Transportation Research Part D 104 (2022) 103196

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

The role of residential consonance and dissonance between couples in travel behavior

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ARTICLE INFO

Keywords:
Built environment
Residential dissonance
Residential consonance
Travel behavior
The Netherlands

ABSTRACT

The present study investigates the extent to which residential consonance/dissonance between couples affected travel behavior at the household level. Using data from the Netherlands, we employed principal component analysis and clustering to construct a residential consonant/dissonant couples typology. We applied gender-specific ordered logistic models to determine the effects of residential consonance/dissonance on travel mode usage. The seemingly unrelated estimation test was used to compare the regression results for male and female household members. The results showed that car use was low among non-urban dissonant men, whereas cycling and train use was high. Non-urban dissonant couples preferred walking. Dissonant men in non-urban areas were less influenced by the residential environment and were inclined to adapt their travel behavior to their partners' travel preferences. Our findings suggest that providing more attractive residential locations and sustainable transport services may enable couples to mitigate residential dissonance.

1. Introduction

Examining built environment-travel behavior associations has garnered increasing interest (Ewing and Cervero, 2001, 2010; Handy et al., 2002). Available evidence suggests that individuals who live in more urbanized areas are inclined to drive less and cycle and walk more (Cervero et al., 2019; Heinen et al., 2010). However, most studies assessing built environment-travel behavior connections are prone to residential self-selection; that is, people relocate to places that align with their travel and locational attitudes and preferences (Cao et al., 2009; Kitamura et al., 1997; Van Wee, 2009). For instance, individuals who favor traveling via public transport may be inclined to settle in an area with easy access to public transit facilities. Travel-related attitudes and preferences may partially explain linkages between the built environment and travel behavior (Gao et al., 2019a). Consequently, if residential self-selection is at play but not adequately accounted for, built environment–travel behavior relations are likely to be overestimated (Cao et al., 2009).

Reviews (Cao et al., 2009; Guan et al., 2020; Mokhtarian and Cao, 2008; van Wee and Cao, 2020) and empirical studies (Cao, 2015a; Cao and Yang, 2017; Jarass and Scheiner, 2018; Lin et al., 2017; Naess, 2014; Scheiner, 2010; Van Wee, 2009) across different

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https://doi.org/10.1016/j.trd.2022.103196

Available online 5 February 2022
1361-9209/

spatial contexts (e.g., North America, Europe, Australia, and China) have discussed ways that residential self-selection may (at least partly) explain people's travel behavior. Some studies found the confounding effects of residential self-selection on relationships between the built environment and travel behavior (Cao et al., 2006; Mokhtarian and Cao, 2008; Van Wee, 2009), whereas other studies have reported only minor effects or null findings (Ettema and Nieuwenhuis, 2017; Scheiner, 2010). Thus, findings regarding the effects of residential self-selection on travel behavior remain inconsistent.

A possible reason for inconclusive findings concerning the effects of residential self-selection on travel behavior is that people may not always be able to move to their ideal locality (Schwanen and Mokhtarian, 2005). This frequently leads to a mismatch between actual and ideal residential locations (i.e., residential dissonance) (De Vos et al., 2012; Schwanen and Mokhtarian, 2004). Numerous studies have investigated the effects of residential consonance and dissonance on travel behavior in the USA (Cao, 2015b; Cho and Rodríguez, 2014; Frank et al., 2007; Schwanen and Mokhtarian, 2004, 2005), Australia (Kamruzzaman et al., 2015; Kamruzzaman et al., 2013a; Kamruzzaman et al., 2013b; Van Acker, 2021), and Europe (De Vos et al., 2012; De Vos and Witlox, 2016; Janke, 2021). Most found that about 25–50% of the participants were residential dissonant (De Vos et al., 2012; Schwanen and Mokhtarian, 2004). This is probably because people usually also consider other criteria (e.g., residential environment and dwelling quality) in addition to transport (Ettema and Nieuwenhuis, 2017). Such a mismatch between desired and actual residential locations could also arise because of financial constraints and demands of other household members (e.g., a better school nearby).

Although most existing studies considered travel-related attitudes indicators of residential preferences, such mode-specific attitudes simply refer to a basic orientation toward travel without considering the relation to residential location decisions (Næss, 2009). Residential preference can be measured using "stated residential preferences" (i.e., people's residential expectation without any constraints) and "revealed residential preferences" (i.e., reasons for residential choice) (Li et al., 2020). Travel-related reasons for residential choice refer to the extent to which travel needs and preferences were considered during the residential location decision process, denoting revealed travel-related residential preferences. Reasons for residential choice are assumed to underlie both the residential choice (e.g., quality of the environment) and the travel-related attitudes (e.g., accessibility). Therefore, this can be considered as more direct indicators of residential self-selection than travel mode attitudes (Kroesen, 2019; Næss, 2009). However, different levels of discordance may exist between the reasons for residential choice and the actual residential choice. For example, individuals who state accessibility is key for choosing the current residential location might not actually live in high-level accessibility areas. Such residential dissonance could be due to differences between the perceived and actual built environment.

In addition, the role of residential self-selection in residential location choice may differ by household type (Janke, 2021). Single-person households probably tend to live in areas that match their preferences because they are less constrained by conflicts between the residential preferences of household members. Conversely, residential location choices of multi-person households may involve negotiations among household members, each having diverse residential preferences (Guan and Wang, 2019b; Janke, 2021), and daily travel decisions need to be aligned with each other's needs (Ho and Mulley, 2015). For instance, a household located in a non-urban area may include a man who prefers living in an urban area (i.e., non-urban dissonant), whose female partner prefers non-urban living (i.e., non-urban consonant). They may experience different levels of residential dissonance because they have different travel preferences.

To align travel preferences, couples need to compromise to optimize residential location choices. For example, among car-deficient households, women have limited car access compared to their male spouses (especially on weekdays) (Scheiner and Holz-Rau, 2012; Tiikkaja and Liimatainen, 2021). Therefore, different degrees of travel mode availability at the household level may exist between couples. In particular, a residential dissonant partner (e.g., a dissonant man living with a consonant woman, and vice versa) may be unable to use their preferred travel modes while living in their actual residential neighborhood compared to residential consonant

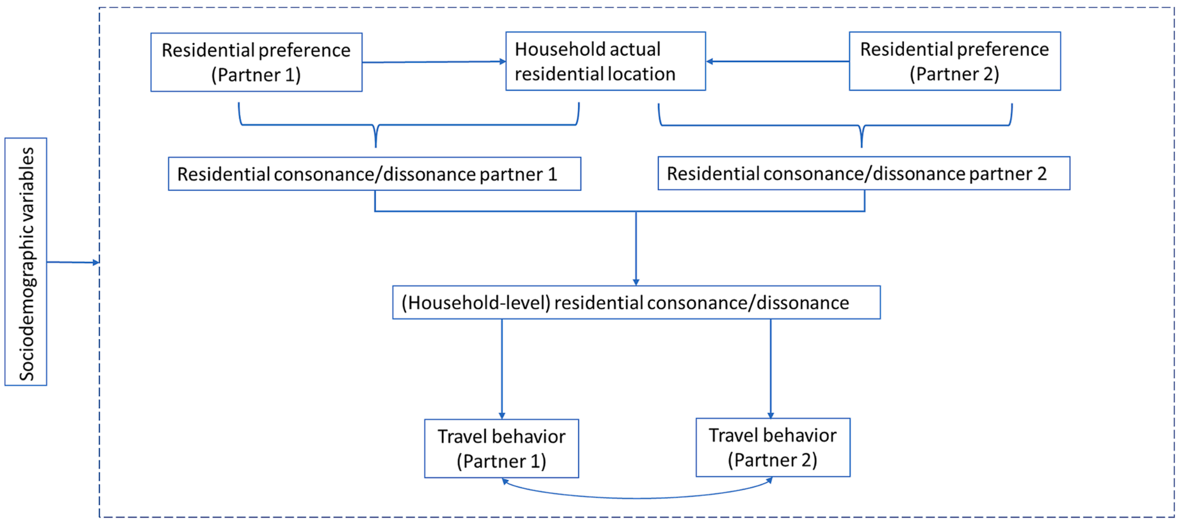

Fig. 1. Conceptual framework Due to data limitation, only woman-man couples were included in this study.

partners. Therefore, it is necessary to examine residential self-selection and dissonance between couples at the household level, as couples may have different preferences of residential location choice.

As we are aware, these *within-household* differences have largely been disregarded in the literature; only a few studies have examined the associations between residential self-selection and travel behavior at the household level (Guan and Wang, 2019a; Yang et al., 2019). However, these studies only considered residential self-selection from the household perspective but did not address the impact of household-level residential dissonance on travel. Among these exceptions, Guan and Wang (2019b) explored the effect of partners' travel attitudes and residential preferences on household residential location and car-ownership decisions. In another study, Guan and Wang (2019a) examined the effect of travel attitudes and the built environment on travel behavior from the perspective of households. However, residential dissonance among household members was unrecognized in both studies. Finally, by considering gender differences in travel attitudes on residential self-selection, Janke (2021) analyzed the distribution of household-level residential dissonance and suggested that women's travel attitudes significantly influence their residential location choice. However, further evidence about the effects of household-level residential consonance/dissonance between couples on travel behavior remains limited.

To address this research gap, we examined how the household-level residential consonance/dissonance between couples *within* a household affects travel behavior. Based on data from the Netherlands, we hypothesized that couples with dissonant partners (e.g., a dissonant man with consonant woman, and vice versa) were more likely to adapt their travel behavior to his/her consonant partner's travel need. Furthermore, dissonant non-urbanities were more likely to use their preferred travel modes than dissonant urbanites regarding residential location. The possible reason is that people living in urban areas may face more constraints in the daily travel, such as traffic congestions. Fig. 1 displays the conceptual model of this study.

2. Materials and methods

2.1. Data and study population

In this observational study, data were obtained from the Netherlands Mobility Panel, which captures changes in individuals' and households' travel behavior related to life events, residential relocations, and other contextual changes (Hoogendoorn-Lanser et al., 2015). Approximately 5,000 respondents from 2,000 households participate in each wave of the web-based questionnaire survey. Participants record their travel trends (e.g., travel modes, travel purpose, trip duration, and distance) for three successive days and provide their demographic and socioeconomic characteristics.

We used data from the 2014 wave (5,551 respondents from 2,095 households) for our analysis because this wave also recorded travel-related attitudes and reasons for residential choice. After excluding single-person households ($N = 535$) and respondents with missing data ($N = 3{,}864$), as well as same-sex couple households (because of underrepresentation; $N = 16$), the final sample comprised 788 participants from 394 households distributed across the Netherlands. Thus, our data incorporated a large variety of geographic contexts.

2.2. Travel mode frequencies as outcome variables

We included five outcome variables: weekly frequency of mode use (car, bike, bus, train, and walking) as done elsewhere (de Haas et al., 2018; Kalter et al., 2021). The panel recorded the self-reported travel mode frequency on a seven-point scale. However, to minimize self-reporting errors for specific travel modes, especially public transport (Kalter et al., 2021), we reclassified travel mode frequency into ordinal variables: *never*, *occasionally* (<three days per month), *regularly* (one–three days per week), and *frequently* (≥four days per week).

2.3. Cluster analysis to identify the neighborhood type

To determine the participants' actual residential location, we used 4-digit postcode areas (PC4). The median PC4 size was 5.5 km^2 with, on average, 1,374 address locations. According to prior studies, variables describing the built environment were selected (Ewing and Cervero, 2010; Wang et al., 2016) and data availability (CBS, 2014a). Address density refers to the number of addresses per km^2. Land-use diversity was measured with the Shannon entropy index based on residential, commercial, manufacturing, leisure, and public utilities (e.g., park, police office, clinic, or hospital). The index has a value of between 0 and 1, with a higher value representing a more even distribution across all kinds of land use per PC4 (Cervero and Kockelman, 1997). In addition, we included street density (i.e., total street length per km^2) (Kadaster, 2012), the number of bus stops, and the Euclidean distance between the geometric center of each PC4 and the nearest train station and supermarket (CBS, 2014b).

Some previous studies used the distance from the residential neighborhood to the city center to classify urban or suburban areas (Cao et al., 2010), while others used population density (De Vos et al., 2012). However, both approaches oversimplify place-based variations in the built environment. For example, even a neighborhood in the countryside or suburbia can have good walkability. We applied a two-step cluster analysis to circumvent this limitation, which can deal with continuous and categorical variables (Kaufman and Rousseeuw, 2009). The appropriate number of clusters was selected using the silhouette value assessing the separation between the clusters (Rousseeuw, 1987). A value closer to $+1$ indicates a more suitable classification.

2.4. Assessment of travel attitudes and residential choices

We grouped the individual items referring to people's travel attitudes toward comfort, pleasure, and safety, as well as their reasons for residential choice. In total, we included 28 travel-related items (e.g., I find traveling by car pleasurable/comfortable/flexible/relaxing) and five reasons for residential choice (Hoogendoorn-Lanser et al., 2015). Each item was recorded on a 5-point Likert scale from 1(strongly disagree) to 5(strongly agree).

Principal component analysis (PCA) with varimax rotation was used to reduce the 33 travel-related and residential choice items linearly to a small set of orthogonal principal components (Bryant and Yarnold, 1995), reflecting the variability of the input data. We used the Kaiser-Meyer-Olkin (KMO) value to examine the adequacy of dimension reduction; KMO values between 0.8 and 1 indicate a suitable factor classification. To select an appropriate number of principal components, we used the latent root criterion with eigenvalues larger than 1.0. Items smaller than 0.5 were discarded.

2.5. Identification of residential dissonance

To identify residential dissonance, we considered the actual residential type and reasons for residential choice of the respondents, following Schwanen and Mokhtarian (2005). Travel-related considerations for location choice and travel mode attitudes probably play different roles in residential self-selection. In particular, travel-related reasons for neighborhood selection were considered more direct indicators of residential location decisions than travel-related attitudes (i.e., a basic orientation toward travel) (Kroesen, 2019). The residential self-selection and dissonance indicators are introduced in Section 3.3.

2.6. Regression analysis

To assess the associations between residential consonance/dissonance and the travel behavior of men and women, we first fitted gender-specific ordered logistic regression models separately for each travel mode frequency (i.e., car, cycling, bus/metro/tram, train, and walking). Model 1 per travel mode frequency was adjusted for travel-related attitudes, life stage-related age groups (grouped into 18–39, 40–59, and 60 + years) (Villanueva et al., 2014), employment status (employed vs. retired, and other unemployed), education (college degree vs. no college degree), and car availability (always available, not always available, no car). At the household level, we included annual gross household income (< €38,800, €38,800–€65,000, and > €65,000) and the presence of dependent children aged < 12 years (yes, no). These individual and household characteristics have been used elsewhere (de Haas et al., 2018; Faber et al., 2021; Gao et al., 2019b). Model 2 for each travel mode further included residential dissonance/consonance, residential location, and their interaction terms.

The seemingly unrelated estimation test (*suest* in Stata) was then used to compare regression results for men and women and test for gender differences in the coefficients between models using Wald chi-squared tests (Weesie, 1999). Given the relatively small sample size, the significance level was set at 0.1, as done elsewhere (Gao et al., 2019b; Mao and Wang, 2020). The analyses were conducted using Stata 16.0 MP (StataCorp, 2019).[1]

3. Results

3.1. Descriptive statistics

We found some gender differences in trip frequency (Fig. 2). Non-parametric Wilcoxon tests showed that car use ($p < 0.001$), cycling ($p < 0.001$), and walking frequencies ($p = 0.002$) were significantly different across genders. In particular, men traveled by car more frequently than women. In contrast, women had the highest cycling frequency. Men and women had similar travel patterns for bus and train trip frequency; most couples were only occasional public transport users.

The other sample characteristics are listed in Table 1. As indicated by the Wilcoxon test, men were more likely to be employed (82%) than women were (70%) ($p < 0.001$). Car availability also varied significantly across genders ($p = 0.001$). Men had a higher proportion of always having access to a car (76%) than women did (66%). This suggests that Dutch residents have high car ownership, and men are given priority over women in using the household's car. A large share of households had middle income (40%) and was less likely to have children aged < 12 years (70%).

3.2. Residential dissonance indicators

3.2.1. Attitudinal and perceptual factors

The principal component analysis revealed four travel-related attitudinal factors and one reasons for residential choice factor. After excluding items with factor loadings < 0.5, 25 items (21 statements concerning travel attitudes and four concerning reasons for residential choice) remained for factor extraction. The four travel-related attitudinal factors (i.e., car, bus/tram/metro, train, and

[1] To run the *suest* command, we first used ordered logistic regression models stratified by gender. The models were saved for comparison using the post-estimate command (*est store*). Then, the models were compared using the *suest* command. The advantage of *suest* is that it calculates the variance–covariance matrix of the coefficients and is applicable to different outcomes (e.g., binary, ordinal, nominal, and count).

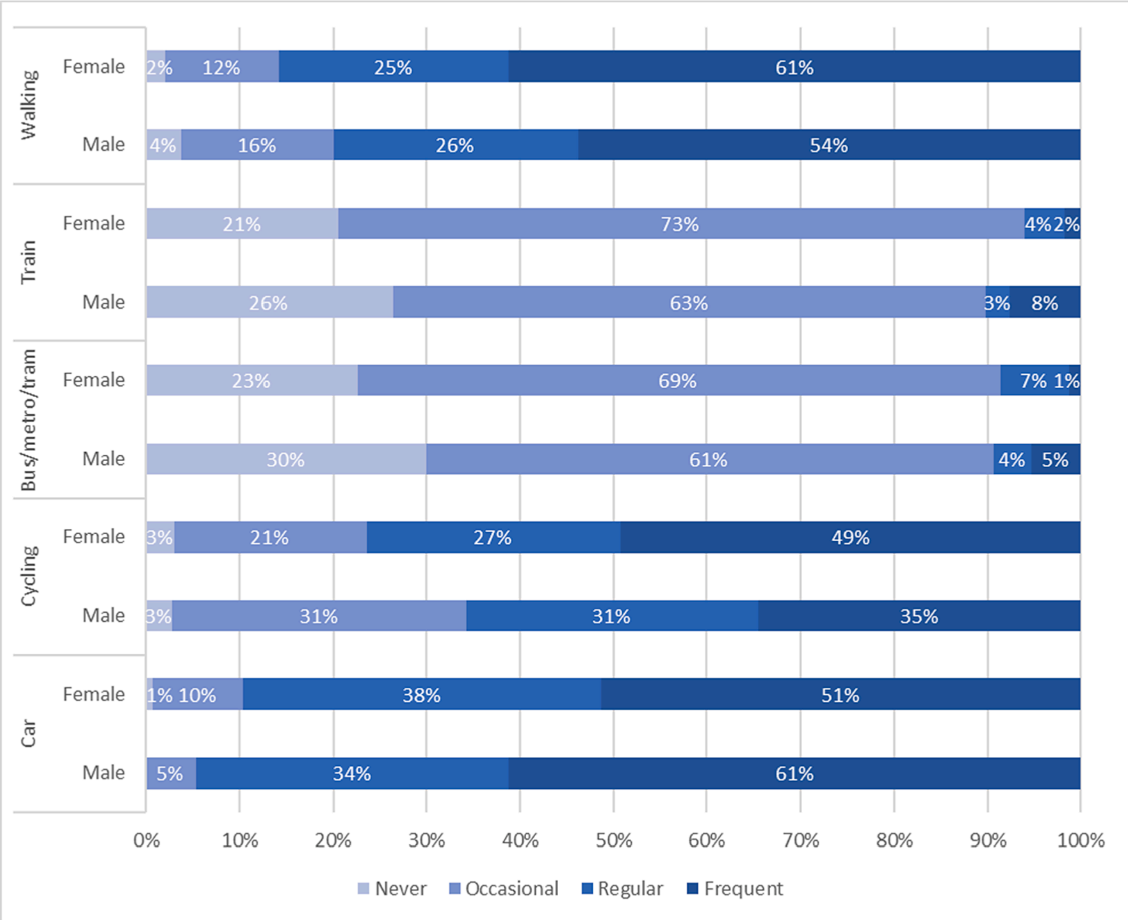

Fig. 2. Trip frequency by gender within the same household ($N = 788$).

Table 1
Descriptive statistics.

Variable	Total sample ($N = 788$)	Male ($N = 394$)	Female ($N = 394$)	p-value[a]
Individual characteristics				
Age				0.000
18–39	28.7%	26.9%	30.5%	
40–59	55.1%	54.6%	55.6%	
60+	16.2%	18.5%	14.0%	
Education				0.048
No college degree	55.6%	52.8%	58.4%	
With college degree	44.4%	47.2%	41.6%	
Employment status				0.000
Employed	76.1%	82.0%	70.3%	
Retired and other unemployed	23.9%	18.0%	29.7%	
Car availability				0.001
Always available	71.3%	76.1%	66.5%	
Not always available	21.8%	19.8%	23.9%	
No car available	6.9%	4.1%	9.6%	
Household characteristics				
Gross household income				
< €38,800	25.1%			
€38,800–€65,000	39.6%			
> €65,000	35.3%			
Children aged < 12 years				
No	69.8%			
Yes	30.2%			

[a] p-values were based on Wilcoxon tests, $p < 0.05$ was considered significant.

cycling) explained 64% of the variance in the input data (Table 2). The KMO value was 0.85, indicating that the included items were adequate for factor extraction (Hair et al., 2009). Reasons for residential choice (i.e., pro-accessibility of residential location) represented 58.9% of the variance, with a KMO value of 0.766 (Table 3). Cronbach's α for each factor showed high reliability and acceptable internal consistency.

3.2.2. Neighborhood classification

The actual residential locations were clustered into urban and non-urban areas. The average silhouette value across the two clusters was 0.5, indicating a fairly good separation (Rousseeuw, 1987). We found substantial differences between the two clusters (Table 4). The only exception was the number of bus stops per PC4 area. The Wilcoxon test showed no significant differences at the 5% level, implying a well-developed public transport infrastructure and good service provision across the Netherlands. Multicollinearity was not present between the built environmental variables, with all Pearson correlation coefficients below $\pm$ 0.8 (Freedman et al., 1991).

To identify residential dissonance, we considered the actual residential type and reasons for residential choice of participants. We used travel-related reasons for residential location choice because they allow a more straightforward indication of self-selection (Ettema and Nieuwenhuis, 2017; Næss, 2009). The PCA-based factor score (F) of pro-accessibility was used to differentiate between individuals in urban and non-urban areas regarding the level of residential dissonance/consonance. A positive score (F greater than 0) indicated a higher level of consonance among urban residents, whereas a negative score ($F < 0$) indicated that non-urban residents were more likely to have a higher level of residential consonance. Referring to previous literature (De Vos et al., 2012; Schwanen et al., 2004), we distinguished four types of dissonant indicators at the individual level by combining dissonance with actual residential location type: consonant urbanites, consonant non-urbanites, dissonant urbanites, and dissonant non-urbanites. Combining this classification with the reasons for residential choice factor, four types of residential households were distinguished: 1) residential consonant households (both partners live in their preferred neighborhood (both consonance)), 2) residential dissonant households for both partners (both partners live in an area different from their preferred neighborhood (both dissonance)), 3) female consonant/male dissonant households, and 4) male consonant/female dissonant households.

3.3. Residential dissonance distribution

Regarding residential dissonance at the household level by residential location (Fig. 3), the largest share was of residential consonant households in both urban (46%) and non-urban (48%) areas. More residential consonant females lived in urban areas than their male partners regarding residential dissonant households. In contrast, more males lived in non-urban areas with residential consonance than their female partners.

As for travel mode frequency at the household level (Fig. 4), non-urban residents (both consonants and dissonants) predominantly used cars, and car use was the lowest among urban consonants. Furthermore, people in non-urban areas were comparatively less likely to use public transport. Most people were occasional public transport users in our sample, while dissonant non-urbanites were inclined to cycle, implying that most daily facilities were within cycling distance in smaller towns (Ettema and Nieuwenhuis, 2017). Regarding walking frequency, urban consonants and non-urban dissonants engaged in walking the most, suggesting that the built environment imposes fewer restrictions on walking behavior.

Table 2
Factor loadings for travel mode attitudes.

Factor	Questionnaire items	Factor loadings per principal component			
		1	2	3	4
Bus/tram/metro attitude factor (α = 0.890)	Traveling by bus, tram, or metro is pleasurable	0.810			
	I find traveling by bus, tram, or metro to be comfortable	0.803			
	I find traveling by bus, tram, or metro to be flexible	0.801			
	Traveling by bus, tram, or metro saves me time	0.786			
	I find traveling by bus, tram, or metro to be relaxing	0.769			
Car use attitude factor (α = 0.848)	Travelling by car is pleasurable		0.840		
	I find traveling by car to be comfortable		0.808		
	I find traveling by car to be flexible		0.751		
	I find traveling by car to be relaxing		0.740		
	Traveling by car saves me time		0.705		
	Traveling by car is safe		0.705		
Cycling attitude factor (α = 0.838)	Cycling is pleasurable			0.855	
	I find cycling to be relaxing			0.846	
	I find cycling to be comfortable			0.802	
	I find cycling to be flexible			0.716	
	Cycling is safe			0.621	
	Cycling saves me time			0.603	
Train use attitude factor (α = 0.875)	I find traveling by train to be relaxing				0.808
	I find traveling by train to be comfortable				0.797
	Traveling by train is pleasurable				0.793
	Traveling by train is safe				0.767

Kaiser-Meyer-Olkin (KMO) value = 0.850; Bartlett's test of sphericity (chi-square = 9128.191, $p < 0.001$); α = Cronbach's alpha.

Table 3
Factor loadings for reasons for residential choice.

Factor	Questionnaire items	Factor loadings per principal component
Pro-accessibility ($\alpha = 0.765$)	The presence of a bus, tram, or metro station within walking distance was an important factor in my choice to reside at my current address	0.812
	The presence of a train station within walking or cycling distance was an important factor in my choice to reside at my current address	0.790
	A short walking and/or cycling distance to shops was an important factor in my choice to reside at my current address	0.784
	The cycling distance to my workplace(s) was an important factor in my choice to reside at my current address	0.676

Kaiser-Meyer-Olkin (KMO) value = 0.766; Bartlett's test of sphericity (chi-square = 783.080, $p < 0.001$); α = Cronbach's alpha.

Table 4
The built environment characteristics.

Variable	Urban	Non-urban	p-value[a]
	Mean (*SD*)	Mean (*SD*)	
Address density (1,000 addresses per km^2)	2.04 (1.17)	0.49 (0.04)	0.000***
Land use diversity	0.55 (0.15)	0.644 (0.13)	0.000***
Street density (km/km^2)	23.85 (4.58)	10.38 (5.47)	0.000***
Number of bus stops	17.75 (9.69)	17.29 (11.42)	0.549
Distance to train station (km)	2.67 (1.53)	6.52 (6.00)	0.000***
Distance to supermarket (km)	0.74 (0.25)	1.52 (0.81)	0.000***

[a] *p*-values were based on *t*-tests; *SD* = standard deviation.

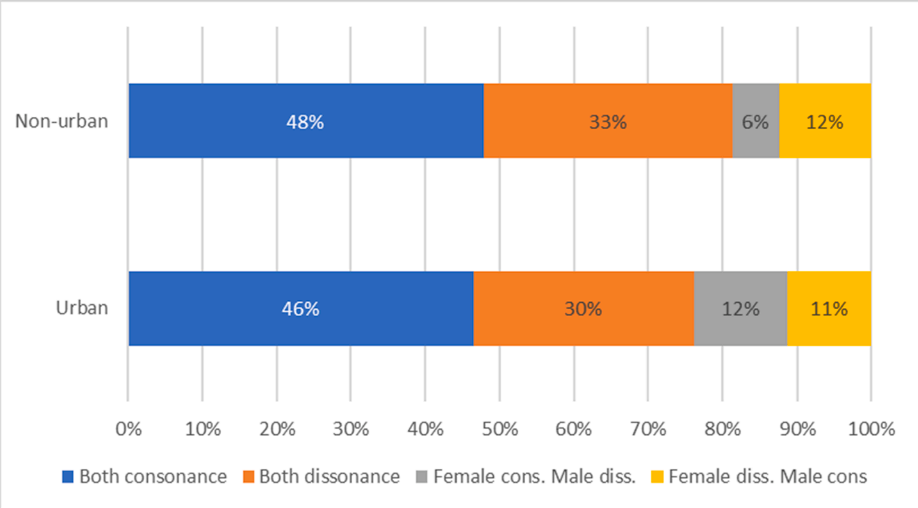

Fig. 3. Residential dissonance at the household level by residential location (cons. = consonance, diss. = dissonance).

3.4. Effects of residential dissonance on travel behavior

Tables 5–9 summarize the ordered logistic regression results of residential self-selection and dissonance for different travel mode frequencies stratified by gender. The estimated regression models (Model 1_{car}, Model $1_{cycling}$, Model $1_{public\ transit}$, Model 1_{train}, and Model 1_{walk}) show a reasonable fit, as indicated by the pseudo R^2 values, ranging from 0.195 to 0.243. After adding the residential neighborhood type variables (Model 2_{car}, Model $2_{cycling}$, Model $2_{public\ transit}$, Model 2_{train}, and Model 2_{walk}), the pseudo R^2 values increased by at least 10%, indicating residential consonance/dissonance influences travel behavior.

Using the *suest* test, we found no significant difference between females and males for car use (Model 1_{car}: $\chi^2 = 6.66$, $p = 0.94$; Model 2_{car}: $\chi^2 = 11.32$, $p = 0.94$), train use (Model 1_{train}: $\chi^2 = 21.49$, $p = 0.09$; Model 2_{train}: $\chi^2 = 23.70$, $p = 0.26$), or walking (Model 1_{walk}: $\chi^2 = 16.27$, $p = 0.30$; Model 2_{walk}: $\chi^2 = 22.03$, $p = 0.33$). Results from Model 1 indicate no gender difference in the effects of residential consonance/dissonance on travel behavior. For cycling (Model $1_{cycling}$: $\chi^2 = 29.76$, $p = 0.08$; Model $2_{cycling}$: $\chi^2 = 34.70$, $p = 0.02$) and bus/tram/metro use (Model $1_{public\ transit}$: $\chi^2 = 26.48$, $p = 0.02$; Model $2_{public\ transit}$: $\chi^2 = 31.64$, $p = 0.04$), the models revealed significant gender differences. We subsequently conducted pairwise tests (Wald chi-squared tests) to compare the estimated coefficients by gender (Tables 5–9). Some coefficients (e.g., dissonant man with consonant woman, and residential dissonant households) differed significantly ($p < 0.1$) across genders.

Although no statistically significant gender differences were observed for car use frequency, the regression coefficients suggested that both females and male partners with a positive attitude toward car use drove more frequently. Positive attitudes toward cycling decreased car use frequency among males (Model 1_{car}). After adding the residential dissonance (Model 2_{car}), travel attitudes remained significant ($p < 0.001$), suggesting that mode-specific attitudes have an independent effect on car use. Males in non-urban areas used a car more frequently than female partners. However, when adding the interaction term between residential dissonance and residential location, we observed that non-urban dissonant males with dissonant female partners were less likely to drive, while no significant results were found for non-urban dissonant females with dissonant male partners.

In Model $1_{cycling}$, females who had a positive attitude toward train use also cycled more frequently. This association was not observed for male partners. A positive attitude toward cycling encouraged both males and female partners to cycle more. However, no statistically significant difference was observed. After considering the residential dissonance (Model $2_{cycling}$), non-urban dissonant males with dissonant or consonant female partners cycled more frequently, while no such association was found for non-urban

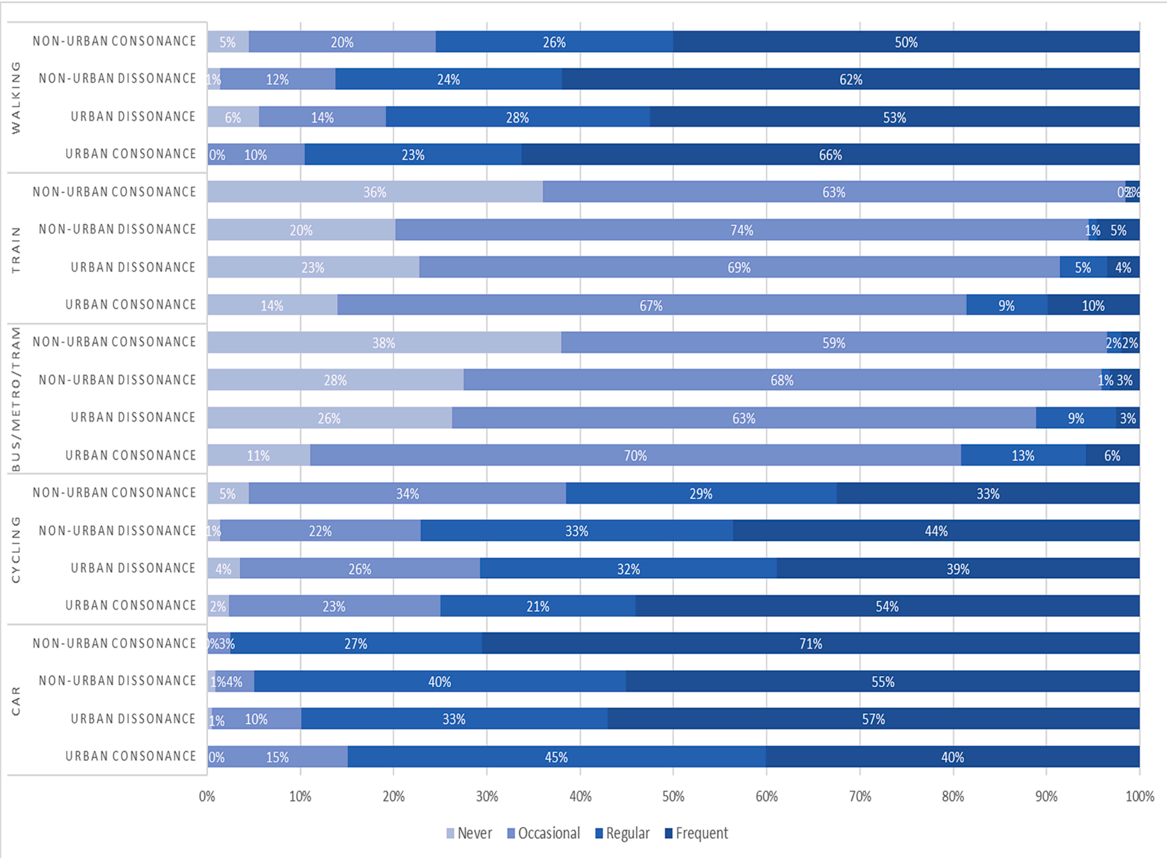

Fig. 4. Trip frequency by residential neighborhood type ($N = 788$).

dissonant females with dissonant or consonant male partners.

For public transit frequency, after adding residential dissonance (Model $2_{\text{public transit}}$), positive attitudes toward bus/tram/metro and train use remained significant for both male and female partners. Conversely, couples who had a positive attitude toward car use used public transport less frequently. Although statistically insignificant across genders, males in residential dissonant households made less use of public transport, while no such association appeared for female partners. Non-urban consonant men living with dissonant women were more likely to use public transport. Again, no such evidence exists for female partners.

Regarding travel-related attitudes toward different modes, train use attitudes were positively correlated with public transit use. A positive attitude toward bus/tram/metro increased train use frequency for male and female partners (Model 1_{train} and Model $2_{\text{public transit}}$). Men who had a positive attitude toward cycling also frequently used trains, whereas their female partners did not. After incorporating the residential dissonance (Model 2_{walk}), men and women who had a positive attitude toward cycling showed a higher walking frequency, indicating synergic effects between walking and cycling.

We also found some gender-specific differences in sociodemographic variables. For example, males without cars showed a high probability of cycling more frequently. We did not observe significant results for females. Further, males with a college degree tended to cycle more than females with a college degree. Meanwhile, females with dependent children were more likely to cycle, but no such relationship was found for males with dependent children. Higher-income females and females who did not always have a car available tended to use public transport. In contrast, males from middle-income households cycled less frequently compared to female partners.

To test the robustness of our results, we also refitted the models with an alternative reclassification based on the seven-point scale response categories of the outcome variables used in the panel (i.e., *never*, *< one day per year*, *one–five days per year*, *six–eleven days per year*, *one–three days per month*, *one–three days per wee*k, and *≥ four days per week*). We found that our main model with four category outcomes performed better in terms of the proportional odds assumption, but we did not report these results here. Furthermore, no noticeable differences were observed in the directions of the associations and their statistical significance.

4. Discussion

4.1. Interpretations of main findings

Several studies have investigated how residential self-selection and dissonance affect travel behavior at the individual level (De Vos

Table 5
Regression results of car frequency.

Variables	Model 1_{car}					Model 2_{car}				
	Man		Woman		Difference test	Man		Woman		Difference test
	Coef.	S.E.	Coef.	S.E.	χ^2	Coef.	S.E.	Coef.	S.E.	χ^2
Age (ref. = 18–39)										
40–59	0.177	0.365	−0.196	0.310	0.820	0.128	0.366	−0.223	0.309	0.700
60+	0.090	0.560	−0.566	0.457	0.900	0.087	0.558	−0.558	0.461	0.850
Education (ref. = No college degree)										
With college degree	0.031	0.251	−0.103	0.229	0.170	0.161	0.253	−0.109	0.234	0.650
Gross household income (ref. = < €38,800)										
€38,800–€65,000	0.155	0.312	0.242	0.291	0.060	0.139	0.314	0.225	0.291	0.050
> €65,000	−0.042	0.382	0.480	0.300	1.360	−0.040	0.385	0.519*	0.305	1.530
Children aged < 12 years (ref. = No)										
Yes	0.500	0.331	0.077	0.283	1.310	0.436	0.327	0.033	0.286	1.120
Employment status (ref. = Employed)										
Retired and other unemployed	−0.662	0.460	−0.444	0.289	0.150	−0.659	0.462	−0.432	0.289	0.160
Car availability (ref. = Always available)										
Not always available	−1.744***	0.295	−1.214***	0.263	1.800	−1.816***	0.299	−1.213***	0.264	2.330
No car available	−2.871***	0.603	−2.213***	0.371	0.830	−2.907***	0.601	−2.282***	0.377	0.750
Travel attitudes										
Bus/tram/metro attitudes	−0.206	0.120	−0.118	0.115	0.280	−0.166	0.120	−0.102	0.118	0.140
Car attitudes	0.765***	0.146	0.718***	0.115	0.070	0.788***	0.147	0.728***	0.118	0.110
Cycling attitudes	−0.621***	0.162	−0.400***	0.118	1.260	−0.617***	0.168	−0.373***	0.120	1.480
Train attitudes	0.146	0.122	0.163	0.107	0.010	0.163	0.125	0.180	0.110	0.010
Residential dissonance (between couples) (ref. = Both residential consonant)										
Both residential dissonance						0.570	0.423	0.103	0.378	0.910
Dissonant man with consonant woman						0.363	0.611	−0.093	0.460	0.530
Consonant man with dissonant woman						−0.119	0.539	−0.084	0.545	0.000
Residential location (ref. = Urban)										
Non-urban	0.485*	0.249	0.460**	0.228	0.010	1.224***	0.387	0.823**	0.362	0.760
Residential dissonance (between couples) × residential location										
Both residential dissonance × non-urban						−1.555***	0.558	−0.662	0.520	1.690
Dissonant man with consonant woman × non-urban						−0.641	0.841	−0.836	0.861	0.040
Consonant man with dissonant woman × non-urban						−0.962	0.770	−0.621	0.680	0.170
Pseudo R^2	0.227		0.195			0.243		0.201		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Coef. = coefficient; S.E. = standard error.

et al., 2012; Kamruzzaman et al., 2013a; Naess, 2014; Schwanen and Mokhtarian, 2005; Van Acker, 2021) and the household level between couples (Guan and Wang, 2019b; Ho and Mulley, 2015; Janke, 2021). However, those studies considered only residential self-selection from the household perspective but did not address the impact of household-level residential dissonance on travel. To our knowledge, the present study is among the first to explore the impact of heterogeneity in residential consonance/dissonance between couples within the same household on travel behavior.

Our findings suggest that residential consonance/dissonance between couples in a household explains their travel behaviors. The effects of residential consonance/dissonance may differ across travel modes. For example, non-urban dissonant men had low car use frequency and high cycling and train use frequencies. This suggests that dissonant men in non-urban areas were less influenced by the residential environment, emphasizing the importance of personal preferences among men. Further, dissonant non-urbanites (both partners) were more likely to use their preferred travel modes than dissonant urbanites, which agrees with earlier research (De Vos et al., 2012). This is probably because residents may face more physical constraints (e.g., traffic congestion and parking problems) than residents in non-urban areas. Also, compared to previous individual-level studies on residential consonance and dissonance (Kamruzzaman et al., 2013a; Van Acker, 2021), our results show a pronounced difference in residential consonance/dissonance between couples regarding travel behavior. This trend is particularly true for men residing in non-urban areas who prefer urban built environments (dissonant non-urbanites), and are inclined to adjust their travel behavior in response to their female partners' travel needs (Guan and Wang, 2019b).

In addition, non-urban dissonant men living with consonant female partners were inclined toward cycling and using public transport. This inclination may be attributed to the Dutch cycling culture and the cycling-friendly environment in smaller Dutch towns.

Table 6
Regression results of cycling frequency.

Variables	Model $1_{cycling}$					Model $2_{cycling}$				
	Man		Woman		Difference test	Man		Woman		Difference test
	Coef.	S.E.	Coef.	S.E.	χ^2	Coef.	S.E.	Coef.	S.E.	χ^2
Age (ref. = 18–39)										
40–59	0.549**	0.277	0.561**	0.271	0.000	0.610**	0.282	0.624**	0.276	0.000
60+	0.979**	0.465	0.514	0.458	0.500	0.983**	0.474	0.634	0.468	0.270
Education (ref. = No college degree)										
With college degree	0.536**	0.224	−0.210	0.223	5.850***	0.493**	0.233	−0.209	0.230	4.880**
Gross household income (ref. = < €38,800)										
€38,800–€65,000	−0.548*	0.292	0.108	0.287	3.190*	−0.561*	0.293	0.145	0.294	3.650**
> €65,000	−0.468	0.320	−0.184	0.301	0.470	−0.502	0.326	−0.219	0.305	0.450
Children aged < 12 years (ref. = No)										
Yes	−0.156	0.243	0.559**	0.253	4.850**	−0.108	0.251	0.661**	0.264	5.160**
Employment status (ref. = Employed)										
Retired and other unemployed	0.116	0.411	−0.065	0.286	0.120	0.108	0.427	−0.117	0.287	0.180
Car availability (ref. = Always available)										
Not always available	1.450***	0.292	0.631**	0.285	3.690**	1.399***	0.290	0.679**	0.297	2.800*
No car available	1.185*	0.622	0.471	0.489	0.880	1.112*	0.646	0.573	0.477	0.490
Travel attitudes										
Bus/tram/metro attitudes	0.022	0.114	0.078	0.119	0.120	0.003	0.116	0.036	0.125	0.040
Car attitudes	−0.474***	0.118	−0.493***	0.119	0.020	−0.467***	0.120	−0.487***	0.120	0.020
Cycling attitudes	1.301***	0.142	1.098***	0.162	0.990	1.296***	0.145	1.081***	0.163	1.080
Train attitudes	−0.003	0.105	0.282**	0.141	2.900*	−0.012	0.108	0.292**	0.144	3.140*
Residential dissonance (between couples) (ref. = Both residential consonant)										
Both residential dissonance						−0.466	0.374	−0.032	0.359	0.850
Dissonant man with consonant woman						−0.422	0.467	−0.186	0.566	0.120
Consonant man with dissonant woman						−0.235	0.458	0.676	0.520	3.340*
Residential location (ref. = Urban)										
Non-urban	−0.069	0.225	−0.234	0.215	0.330	−0.584	0.357	−0.485	0.313	0.050
Residential dissonance (between couples) × residential location										
Both residential dissonance × non-urban						0.895*	0.507	0.661	0.475	0.150
Dissonant man with consonant woman × non-urban						1.281*	0.684	−0.065	0.796	1.620
Consonant man with dissonant woman × non-urban						0.643	0.565	0.150	0.704	0.410
Pseudo R^2	0.216		0.141			0.222		0.151		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Coef. = coefficient; S.E. = standard error.

Therefore the non-urban characteristics had limited effects on cycling behavior. The consonant female partners who prefer to live in non-urban areas tend to use private cars in the household. These findings also imply that long-distance trips may require negotiation between couples, as women may need to take on more household responsibilities in the absence of their partners. Thus, female partners who preferred to live in non-urban areas tended to use the household's car, which is in line with another Dutch study (Schwanen, 2011).

What is more, regarding the insignificant results of residential dissonance for women, it is imperative to bear in mind that most women in the Netherlands work part-time (Gao et al., 2019a; Van der Lippe et al., 2011). A large share of partner households consisted of a man earner and a woman homemaker (with a part-time job). This household structure possibly leads to disproportionate family tasks and social and spatial resources (e.g., economic dependence and travel mode choice) (Babcock and Laschever, 2009). It is possible that rather than personal preferences, household and job obligations may force women to use a car to reduce the complexity of their daily activities and travel. This suggests that other travel- and non-travel-related factors should also be considered when examining women's travel behavior, especially in residential dissonance households.

Non-urban dissonant couples were more likely to walk, suggesting that natural green spaces in non-urban areas promote walking even though the area is not the couples' preferred place of residence. These findings enrich the literature on residential self-selection by providing a more nuanced perspective that differentiates the effects of residential consonance/dissonance within couples on travel behavior. Taken together, these findings suggest that personal travel behavior is likely to be influenced by residential consonance/ dissonance between couples in a household. Moreover, female and male partners exhibit distinct sensitivity to the residential characteristics regarding partners' positions in the household.

Regarding travel-related attitudes among different travel modes, our results also suggest an independent effect of travel-related attitudes on travel behavior in addition to residential consonance and dissonance. We also found asymmetrical mechanisms

Table 7
Regression results of public transit frequency.

Variables	Model 1$_{public\ transit}$					Model 2$_{public\ transit}$				
	Man		Woman		Difference test	Man		Woman		Difference test
	Coef.	S.E.	Coef.	S.E.	χ^2	Coef.	S.E.	Coef.	S.E.	χ^2
Age (ref. = 18–39)										
40–59	−0.486	0.312	−0.298	0.358	0.230	−0.447	0.316	−0.274	0.362	0.200
60+	−0.610	0.523	0.241	0.448	1.970	−0.674	0.533	0.218	0.456	2.120
Education (ref. = No college degree)										
With college degree	0.509**	0.244	0.652**	0.263	0.170	0.467*	0.250	0.623**	0.273	0.190
Gross household income (ref. = < €38,800)										
€38,800–€65,000	0.341	0.313	0.510	0.326	0.210	0.306	0.315	0.478	0.332	0.200
> €65,000	0.398	0.354	0.664*	0.355	0.370	0.340	0.361	0.609*	0.363	0.380
Children aged < 12 years (ref. = No)										
Yes	−0.845***	0.295	−0.864***	0.330	0.000	−0.904***	0.299	−0.882***	0.333	0.000
Employment status (ref. = Employed)										
Retired and other unemployed	0.215	0.417	−0.720**	0.298	3.320*	0.204	0.429	−0.751**	0.307	3.320*
Car availability (ref. = Always available)										
Not always available	0.296	0.295	1.112***	0.282	4.820**	0.223	0.307	1.073***	0.287	4.830**
No car available	2.314***	0.594	1.404***	0.528	1.440	2.265***	0.638	1.370***	0.537	1.220
Travel attitudes										
Bus/tram/metro attitudes	0.928***	0.137	0.490***	0.129	6.580***	0.915***	0.140	0.484***	0.132	5.900***
Car attitudes	−0.214***	0.114	−0.137	0.122	0.270	−0.201*	0.114	−0.128	0.122	0.240
Cycling attitudes	−0.057	0.114	−0.088	0.108	0.050	−0.073	0.114	−0.116	0.110	0.090
Train attitudes	0.210*	0.109	0.337***	0.128	0.700	0.214*	0.114	0.312**	0.131	0.380
Residential dissonance (between couples) (ref. = Both residential consonant)										
Both residential dissonance						−0.674*	0.391	−0.738	0.468	0.020
Dissonant man with consonant woman						−0.245	0.443	0.230	0.482	0.650
Consonant man with dissonant woman						−1.241**	0.619	−0.101	0.572	2.420
Residential location (ref. = Urban)										
Non-urban	−0.432*	0.240	−0.643	0.252	0.590	−0.886**	0.355	−1.008**	0.397	0.090
Residential dissonance (between couples) × residential location										
Both residential dissonance × non-urban						0.705	0.529	0.925	0.614	0.110
Dissonant man with consonant woman × non-urban						0.283	1.003	0.443	0.725	0.030
Consonant man with dissonant woman × non-urban						1.464*	0.817	0.272	0.704	1.660
Pseudo R^2	0.160		0.152			0.174		0.165		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Coef. = coefficient; S.E. = standard error.

between travel-related attitudes and travel mode usage. For example, men who had positive attitudes toward bus/tram/metro use and cycling used the train more frequently, and couples who had positive attitudes toward train use made more use of buses. These findings indicate that train use increases the likelihood of bus/tram/metro and cycle usage. In other words, the concordance between travel-related attitudes and travel mode usage was confirmed.

4.2. *Strengths and limitations*

The major contribution of this study is that our analyses showed that couples in a household might have different travel-related residential preferences. In such cases, one of the partners may become a dissonant resident and cannot use their preferred travel modes. We have thus added to an in-depth understanding of residential self-selection by examining residential dissonance/consonance between couples in a household and its impact on travel behavior.

Our study also had some limitations. The one-year data we used did not consider causal statements about the effects of residential consonance/dissonance on travel behavior. For example, people who live in a new residential neighborhood may adapt their travel behavior and attitudes to their current residential location over time to reduce residential dissonance. Thus, we cannot exclude the reverse causality among built environment, travel attitudes, and travel behavior (Kroesen, 2019). We advise that future studies employ longitudinal panel data to address this limitation. Due to data limitations, only heterosexual couples were included. We do not know whether our results are also applicable to homosexual couples. Besides, given the lack of data on "stated residential preferences," we may not fully capture people's residential desires or preferences. Since we focus on the effect of residential dissonance rather than the residential self-selection effect, using reasons for residential choice would be a limitation for examining the effect of residential

Table 8
Regression results of train frequency.

Variables	Model 1_{train} Man		Woman		Difference test	Model 2_{train} Man		Woman		Difference test
	Coef.	S.E.	Coef.	S.E.	χ^2	Coef.	S.E.	Coef.	S.E.	χ^2
Age (ref. = 18–39)										
40–59	−0.610*	0.319	−0.741**	0.355	0.110	−0.581*	0.327	−0.740**	0.355	0.160
60+	−0.040	0.539	−0.506	0.478	0.560	−0.082	0.535	−0.471	0.486	0.39
Education (ref. = No college degree)										
With college degree	0.507**	0.251	0.975***	0.277	1.830	0.381	0.267	0.942***	0.283	2.35
Gross household income (ref. = < €38,800)										
€38,800–€65,000	0.344	0.306	0.519	0.330	0.260	0.339	0.316	0.551	0.336	0.360
> €65,000	0.454	0.367	0.811**	0.355	0.700	0.427	0.382	0.852**	0.366	0.940
Children aged < 12 years (ref. = No)										
Yes	−0.704**	0.305	−0.848***	0.321	0.190	−0.666**	0.314	−0.793**	0.328	0.140
Employment status (ref. = Employed)										
Retired and other unemployed	−0.809**	0.410	−0.140	0.280	1.930	−0.888**	0.416	−0.196	0.286	2.050
Car availability (ref. = Always available)										
Not always available	1.092***	0.313	0.467	0.291	2.530	1.023***	0.315	0.490	0.301	1.770
No car available	2.364***	0.663	0.052	0.588	7.200***	2.287***	0.682	0.082	0.576	6.330***
Travel attitudes										
Bus/tram/metro attitudes	0.432***	0.131	0.275**	0.118	1.07	0.410***	0.132	0.256**	0.123	0.960
Car attitudes	−0.194*	0.112	−0.081	0.125	0.590	−0.176	0.117	−0.084	0.127	0.370
Cycling attitudes	0.259**	0.108	0.037	0.119	2.350	0.249**	0.111	0.021	0.123	2.280
Train attitudes	0.563***	0.126	0.579***	0.159	0.010	0.581***	0.131	0.593***	0.159	0.000
Residential dissonance (between couples) (ref. = Both residential consonant)										
Both residential dissonance						−0.684*	0.399	−0.172	0.520	1.010
Dissonant man with consonant woman						−0.865*	0.477	−0.432	0.445	0.670
Consonant man with dissonant woman						−0.746	0.612	0.237	0.887	1.190
Residential location (ref. = Urban)										
Non-urban	−0.186	0.237	−0.658	0.255	3.050*	−1.014***	0.361	−1.023**	0.416	0.000
Residential dissonance (between couples) × residential location										
Both residential dissonance × non-urban						1.493***	0.556	0.895	0.630	0.790
Dissonant man with consonant woman × non-urban						1.706**	0.707	1.088	0.656	0.720
Consonant man with dissonant woman × non-urban						1.255	0.809	−0.296	1.015	2.260
Pseudo R^2	0.149		0.129			0.164		0.139		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Coef. = coefficient; S.E. = standard error.

dissonance. Moreover, the application of postal codes to delineate the geographic context to assess the built environment is not without criticism. Using people's exact home address would be more accurate, but such data were unavailable (Wang et al., 2021). Finally, future studies should also consider the effects of partner's attitudes and socio-demographics on travel behavior.

5. Conclusions

Our findings prove that residential consonance/dissonance between couples within a household affects travel behavior differently, and this effect may differ by gender for different travel modes. The results showed that non-urban dissonant men had a low frequency of car use while their cycling and train use was high. Moreover, non-urban dissonant couples preferred walking. We also found that non-urban dissonant men living with either dissonant or consonant partners were less affected by the residential environment and relied more on personal preferences and partners' travel demands and preferences.

Our findings imply that policies aimed at reducing car use and promoting sustainable travel may not exert the same impact among each household member when controlling for the self-selection effect. A better understanding of residential dissonance at the household level is needed to integrate the competing issues that male and female partners face concerning the residential location and travel mode choices. Non-urban dissonant men were more likely to use train and bicycle compared to non-urban dissonant women. To afford females living in non-urban areas a good experience of using bicycles and public transportation might encourage sustainable travel behavior in the long term. We suggest that urban and transport planning provide a more attractive residential location and sustainable transport services.

Funding: This work was support by the JSPS Postdoctoral Fellowship for Research in Japan [PE20029].

Table 9
Regression results of walking frequency.

Variables	Model 1_{walk}					Model 2_{walk}				
	Man		Woman		Difference test	Man		Woman		Difference test
	Coef.	S.E.	Coef.	S.E.	χ^2	Coef.	S.E.	Coef.	S.E.	χ^2
Age (ref. = 18–39)										
40–59	0.186	0.249	0.611**	0.272	1.840	0.187	0.261	0.668**	0.270	2.220
60+	−0.109	0.417	0.183	0.420	0.280	−0.175	0.441	0.249	0.437	0.530
Education (ref. = No college degree)										
With college degree	0.270	0.222	0.490**	0.226	0.470	0.200	0.229	0.438*	0.234	0.510
Gross household income (ref. = < €38,800)										
€38,800–€65,000	0.122	0.269	0.132	0.276	0.000	0.099	0.269	0.131	0.290	0.010
> €65,000	0.379	0.306	−0.265	0.302	3.150*	0.374	0.312	−0.322	0.305	3.510*
Children aged < 12 years (ref. = No)										
Yes	−0.206	0.240	0.149	0.259	1.800	−0.227	0.248	0.223	0.251	2.790*
Employment status (ref. = Employed)										
Retired and other unemployed	0.622*	0.361	0.296	0.302	0.470	0.635	0.385	0.182	0.306	0.820
Car availability (ref. = Always available)										
Not always available	0.258	0.239	−0.074	0.260	1.200	0.195	0.249	−0.145	0.278	1.090
No car available	1.505**	0.649	0.041	0.416	3.740**	1.457**	0.673	0.077	0.421	3.070*
Travel attitudes										
Bus/tram/metro attitudes	0.124	0.100	0.111	0.107	0.010	0.093	0.103	0.061	0.110	0.050
Car attitudes	−0.148	0.104	−0.078	0.108	0.260	−0.116	0.105	−0.058	0.109	0.190
Cycling attitudes	0.256**	0.105	0.365***	0.097	0.750	0.231**	0.106	0.361***	0.099	1.000
Train attitudes	−0.052	0.095	−0.063	0.109	0.010	−0.048	0.096	−0.061	0.112	0.010
Residential dissonance (between couples) (ref. = Both residential consonant)										
Both residential dissonance						−0.643*	0.368	−0.617*	0.360	0.000
Dissonant man with consonant woman						−0.418	0.509	−0.774	0.589	0.420
Consonant man with dissonant woman						−0.536	0.413	0.362	0.533	2.340
Residential location (ref. = Urban)										
Non-urban	−0.118	0.217	−0.124	0.213	0.000	−0.663**	0.318	−0.658**	0.330	0.000
Residential dissonance (between couples) × residential location										
Both residential dissonance × non-urban						1.267***	0.486	1.279***	0.485	0.000
Dissonant man with consonant woman × non-urban						0.567	0.733	0.739	0.848	0.040
Consonant man with dissonant woman × non-urban						0.482	0.634	−0.029	0.719	0.380
Pseudo R^2	0.036		0.038			0.046		0.051		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Coef. = coefficient; S.E. = standard error.

CRediT authorship contribution statement

Jie Gao: Data curation, Conceptualization, Methodology, Formal analysis, Visualization, Writing – original draft, Funding acquisition. **Toshiyuki Yamamoto:** Writing – review & editing. **Marco Helbich:** Writing – review & editing.

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.

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