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# Social and environmental sustainability of travelling within family networks

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ABSTRACT

Travelling for the purpose of face-to-face meetings with family members achieves an array of societal and individual benefits. However, much like other types of travelling, it may have a negative impact on the environment, especially when it is performed by car. But how to decrease these negative effects while facilitating this important type of interaction has not been addressed before. The programme suggested by the Sustainable Mobility paradigm seems inadequate in the context of family meetings. In this paper we take a first step. We introduce two simple indicators for assessing the performance of travel mobility within family networks in terms of social and environmental sustainability: frequency of contact and total CO2 output of the related travel. Using data from the Netherlands, a Structural Equation Modelling analysis is applied to identify the effect of individual characteristics, car ownership and residential location on the two indicators. The main findings are that car ownership is associated with low environmental sustainability but with high social sustainability, and that living in core cities and distance between parents and adult children are associated with low sustainability in both dimensions. These results serve as input for a discussion of the opportunities and constraints for increasing sustainability in travelling for meetings in family networks.



## 1. Introduction

This paper is based on two broad premises. The first – that individual and societal benefits are inherent to interaction within social networks. The second – that travel mobility, which serves to achieve these benefits (De Vos et al., 2013), may come at a cost in terms of its impact on the environment. The potential benefits from interaction may be: receiving support, accumulation of social capital, and an increase in an individual's subjective well-being (Lelkes, 2006; Martin and Westerhof, 2003; Pichler, 2006). These benefits from social meetings are already important but might become even more so in the future. The on-going retreat and re-organization of the welfare state in Western countries means that the reliance of the individual on one's own personal network, especially for support and care purposes, is likely to increase. Thus the expected increase in the need for social meetings will require more travel mobility. On the other hand, issues such as climate change or the depletion of non-renewable energy sources add pressure to reduce the environmental footprint of transport systems. Experts agree that the current levels of and future increase in greenhouse gas emissions are unsustainable (International Energy Agency, 2009). Accordingly, governments have committed themselves to greenhouse gas emissions targets until 2020 (EC, 2009). The main challenge in the near future is the development of a sustainable transport system, which is defined as a system that meets the needs of individuals and society while minimizes waste and emissions (see Litman, 2015). In particular, this system does not compromise “the ability of future generations to meet their own needs” (Zito and Salvo, 2011, p.180). In other words, for sustainability to be reached, the goal of achieving the benefits should be considered in concert with the associated costs (Zandvliet et al., 2005).

Car usage has been identified as the single most important contributor of travel related pollutants that are harmful for the ecosystem, for example carbon dioxide (CO2) and Nitrogen Oxides (NOx). Consequently, research has tried to identify ways in which travel behaviour could be amended in order to decrease such emissions. Famously Banister (2008) laid out four key conditions that are necessary for a transformation to a more sustainable mobility system: reducing frequency of travel, reducing distance of travel, reducing car use and improve technological efficiency of the

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transport system. Repeatedly evidence was found that highly urbanized regions are the best accommodators of such transformation. It has been argued that the spatial structure of cities is comparatively favourable to at least part of the goals of the sustainable mobility paradigm (Banister, 2008): daily travel distances in urban areas are indeed shorter (Dieleman et al., 2002; Handy, 1996; Holz-Rau et al., 2014) and car use is significantly lower, for example for commuting, leisure and shopping trips (Schwanen et al., 2001).

The research so far has mainly focused on the transition to a more sustainable mobility in economic related activities like commuting and shopping. These are rather high frequency trips around which the daily schedule is planned (Neutens et al., 2011; Schwanen et al., 2008), and where in some cases the individual has multiple destinations to choose from (for example, a choice of a supermarket for the daily shopping). Hence they provide a relatively clear room for planning intervention. Thus, if locations of these activities are concentrated within urban centres in combination with a sufficiently large housing supply, it is expected that the goals will be reached to some extent. Still the question remains whether this holds for other activities as well. Previous studies already pointed to potential conflicts. For example, policies aiming at CO2 emission reduction in everyday travel, like commute and maintenance journeys, may actually increase CO2 emission output for leisure trips (Holden and Linnerud, 2011).

Rather than looking at travelling for economic purposes, in this paper we specifically explore travelling for social purposes, an under-researched but vital activity. Earlier research in the UK investigated the association of individual, household and environmental characteristics with household-level CO2 emissions for social and leisure travel (Brand et al., 2013). Here our goal is to explore the intersection of the two dimensions: environmental sustainability and social sustainability. We focus on a particular type of social activity, that of face-to-face contact between adult children and their parents. Contact between family members is interesting as it sets a unique challenge in terms of mobility planning. Stern and Messer (2009) point out two key ones. First, one chooses their friends, based on shared interests or experiences, while one does not choose one"s (biological) family. Second, friends tend to live within relatively short distance, as they are frequently neighbours, colleagues or members of the same club, which is not necessarily true of family members (Carrasco et al., 2008; Kowald, 2015; Stern and Messer, 2009; however cf. Carrasco and Cid-Aguayo, 2012). In addition to these two challenges, there is the need and normative obligation of face-to-face meetings with family members, that only to a lesser extent applies to friendships (Lee et al., 1994). Thus, from a societal perspective reducing frequency of travel seems undesirable.

These challenges give rise to the question to what extent within this context the two goals of social and environmental sustainability are in conflict with each other or that we could identify situations in which they are not. Furthermore, constraints and opportunities for moving from the former situation to the latter can be identified. Therefore the main research questions are: 1. How do family networks perform from a mobility perspective in terms of social and environmental sustainability? 2. What are the opportunities for and constraints to increasing sustainability in mobility in family networks? The empirical part of this study centres on the Netherlands. Our aim is to contribute to transport planning research by demonstrating how a focus on a single yet important social activity can give us insight into challenges of developing sustainable transport policy.

The next section details the conceptual model of this study, followed by a description of the data and variables. Section 4 provides descriptive statistics and Section 5 the results of the path analysis estimation. Section 6 discusses the implications of the results for increasing sustainability of family meetings and Section 7 concludes.

## 2. Conceptual framework

### 2.1. An indicator for social sustainability

Travelling for social purposes has both positive and negative effects for the individual and society. For the positive effects of mobility we limit our investigation to the role mobility plays in enabling face-to-face meetings, an important factor in the cohesion of communities (Litman, 2015). As an indicator for face-to-face meetings we deploy a simple measure for the social performance of a family network: frequency of annual face-to-face contact between parents and adult children. This variable is commonly used in previous research on intergenerational contact (Bucx et al., 2008; Grundy and Shelton, 2001; Lawton et al., 1994) as an indicator for the dimension of parent-child association within intergenerational solidarity model framework (Bengtson and Roberts, 1991).

### 2.2. An indicator for environmental sustainability

CO2 emissions are the biggest contributor of greenhouse gases to global warming (Brand and Preston, 2010) and their reduction is a central component of policies aiming at minimizing the negative impacts of transport emissions (Banister et al., 2011). CO2 emissions affect a multitude of dimensions of the environment and health (Banister, 2008). CO2 is used as a proxy for other greenhouse gases that are produced by the transport system (Nocera et al., 2012). As an indicator of the environmental effect of mobility for family meetings we use total annual CO2 output produced by travelling for meetings between parents and children. This indicator consists of both CO2 produced by adult children who travel to meet their parents and by parents who travel to meet their adult children.

### 2.3. Two-dimensional space of the sustainability of family networks

Fig. 1 schematically presents a two-dimensional space of the potential relationships between the social performance of family networks on the x-axis and the environmental performance related to travelling for face-to-face contact between adult children and their parents on the y-axis. Every family network can be placed anywhere in that space. The more positive the values along the X axis, the more frequent the family visits are; the more positive the values along the Y axis, the more environmentally

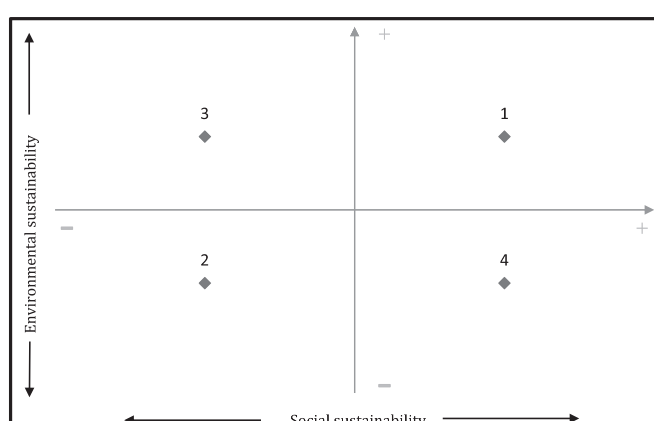


**Fig. 1.** Potential relationships between environmental and social sustainability.

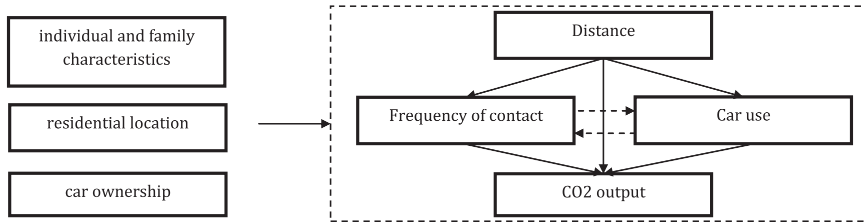


**Fig. 2.** Model explaining CO2 output for meetings between adult children and parents.

sustainable the associated travel is. Positive and negative values in this chart could be seen as relative to the average.

Four examples for family networks are presented in the figure. Type 1 is an example of a family network that has a high frequency of interaction and the associated travel is highly environmentally sustainable. Type 2 is the opposing case in which the family network has a relatively low frequency of interaction and has environmentally unsustainable travelling behaviour. Type 3 and 4 are the mixed cases. Type 3 is where interaction is relatively infrequent but travelling is environmentally sustainable, while Type 4 is where contact is frequent and travelling is environmentally unsustainable. Each of these cases may have a different implication for the planning of the transport landscape and therefore we first need to identify which conditions, in terms of geographic and socio-demographic characteristics of families, are associated with each of these types.

The relationships that are considered in this paper are depicted in Fig. 2. Our environmental indicator of total CO2 emissions is the direct outcome of three characteristics of travel: frequency of meetings, distance separating adult children and their parents and whether travelling for those meetings was accomplished using a car. All three are expected to have a positive direct impact on CO2 output. The longer the travel distance, the higher the frequency and the more car use – the higher the total CO2 output. In addition to the direct effects, we also included two indirect effects running from distance to total CO2 output: one via frequency and one via car use. The expected sign of the total effect of distance might not be trivial, as for example distance is known to have a negative effect on the frequency of meetings between parents and adult children (Lawton et al., 1994). Not all potential effects could be included in this analysis. The highly complex relationship between the three with potential endogeneity in all directions is the interest of many studies (Van Acker and Witlox, 2010). In our empirical analysis, models that included the effect of frequency of contact on car use and vice versa were initially tested but did not yield superior goodness-of-fit indices and therefore these paths were excluded from the final model. Even higher complexity is reached when other variables like residential location or car ownership are considered (see review by Cao et al., 2009). These are assumed here to be exogenous to distance, frequency and travel mode. The exogenous concepts included in the model were selected based on previous analysis of travel for family meetings in the Netherlands (see: Rubin, 2015; Rubin et al., 2014). In our model, individual and family characteristics are assumed to influence distance, frequency and car use directly and CO2 output indirectly. For example, due to task sharing among siblings in the family (Van Gaalen et al., 2008), whether a person has a sibling is expected to have a negative effect on frequency of contact with the parents and a positive effect on distance. As another example, mothers tend to have a stronger contact with their children than fathers do (Lawton et al., 1994) and so if the adult child"s mother lives alone then contact is expected to be more frequency and distance smaller. Therefore the model accounts for, among other variables, whether the individual has a sibling and for the household composition of her or his parents.

## 3. Data

The data used for this paper are the first wave out of three of the Mobility in Social Networks module, part of the Longitudinal Internet Studies for the Social sciences (LISS) panel administered by CentERdata. Additional background variables such as age, gender and household composition were matched by CentERdata from the Background Variables module. The data were collected in the Netherlands in 2009 through an internet based survey among a representative sample of Dutch speaking residents of the Netherlands, aged 16 and above (for a detailed description of the data, including sampling, response and representativeness, see: Scherpenzeel and Das (2010)). The analysis sample consisted of those respondents who were between 25 and 65 years old. Only respondents who were the head of household or the head"s partner, had at least one parent alive, and did not live with any of their parents or siblings were included. The final sample consisted of 1490 adult child-parent dyads. The other two waves were collected only a short time after the first (in 2010 and 2011) and therefore did not contain enough cases with changes in the core variables of interest to justify including them in the analysis.

The reader should note that in this study all variables are measured from the perspective of the adult child. An earlier analysis showed that adult children are the ones who travel more frequently to meet their parents than vice versa (Rubin and Mulder, 2014). Thus, when analysing the sustainability of travel behaviour in family networks, it is the adult children"s behaviour that should be focused on. The implications of this choice are discussed below.

### 3.1. Endogenous variables

Distance was measured at the town (Dutch: *woonplaats*) level, and was calculated using the distance matrix from the National Accessibility Map (*Nationale Bereikbaarheidskaart*) from which road distance between the respondents' home and their parents' home was derived. Frequency of contact was measured for face-to-face meetings from the perspective of the adult child by using the answers to the question: "Over the past 12 months, how often did you see your mother (or father)". Answers were given on an ordinal 7-point scale of frequencies. For the purpose of the analysis the answers were transformed into a continuous scale of numerical values (values were taken from Van Gaalen et al., 2008) as follows: never (0), once (1), a few times (4), at least once a month (12), at least every week (52), several times a week (156), every day (300).

Car use was operationalised as whether the respondent reported the car to be the main mode generally used to travel to the parent's home during the past year. The data only included information on in-home meetings, thus mode of travel to meetings that took place elsewhere is ignored.

Total CO2 output is a sum of CO2 output (in kilograms) for in-home meetings at the parental and for in-home meetings at the respondents' home. For each travel direction distance of travel was multiplied by the frequency of in-home meetings for that direction and the emission factor (grams per travelled kilometre) of the main mode usually used to travel in that direction. The mode-specific emission factor was based on "well-to-wheel" figures from Statistics Netherlands (for full details see Otten et al., 2014). The options for travel mode were walking, cycling, car, bus/tram/metro, train, and other, which was assumed to be motorcycle. For active modes (walking and cycling) CO2 output was zero. The reader should note that the distance between respondents and parents that live in the same town was imputed as 2 km. This was done to enable non-zero emission values for travelling by car or transit within the same town.

### *3.2. Exogenous variables*

The following individual characteristics included: the respondent"s age, being female, having a partner and the age of the youngest child in the household, which was measured in four categories: 0–5, 6–11, 12–17, no child under 18 (reference). Employment status was also included, using a binary variable indicating being (self)employed. Family characteristics included: does the respondent"s mother live alone and does the respondent have any siblings. Car ownership was measured using three categories: no car, one car (reference), two or more. For residential location we used the definition of Statistics Netherlands for city region (in Dutch: stadsgewest). Three categories were considered: living in the core city of the 22 city regions, living within the suburban ring of these cities, or outside these urban systems (reference).

## 4. Descriptive results

Table 1 presents the sample descriptive statistics. In the sample there is an over representation of females (61%). This over representation might have translated into a bias in total contact frequency, however it is unclear in which direction: on the one hand, women engage more in contact with parents but they also tend to live closer to their parents. Car ownership is higher than the average among the Dutch population (97% in the sample vs 71% in the population, see: Statistics Netherlands, 2010). Residents of the core cities are slightly underrepresented: 25% in the sample versus 28% in the population. Residents in less urban areas are overrepresented: 47% in the sample versus 44% in the population (Statistics Netherlands, 2010).

**Table 1**
Descriptive statistics for categorical and continuous variables.

| | | % | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| *Endogenous variables* | | | | | | |
| Distance | km | | 29.5 | 46.1 | 2 | 323 |
| Frequency of contact | Days | | 62.1 | 69.4 | 1 | 300 |
| Mode | Car | 0.72 | | | | |
| CO2 emissions | kg | | 81.7 | 138.5 | 0 | 138.0 |
| *Exogenous variables* | | | | | | |
| Female | No | 0.39 | | | | |
| | Yes | 0.61 | | | | |
| Age | | | 42.8 | 9.5 | 25 | 65 |
| Has partner | No | 0.19 | | | | |
| | Yes | 0.81 | | | | |
| Age of youngest child under 18 | No | 0.26 | | | | |
| | 0–5 | 0.20 | | | | |
| | 6–11 | 0.16 | | | | |
| | 12–17 | 0.37 | | | | |
| Mother of respondent lives alone | No | 0.64 | | | | |
| | Yes | 0.35 | | | | |
| Respondent has a sibling | No | 0.06 | | | | |
| | Yes | 0.94 | | | | |
| Respondent is employed | No | 0.19 | | | | |
| | Yes | 0.81 | | | | |
| Car ownership | No car | 0.03 | | | | |
| | 1 | 0.54 | | | | |
| | 2+ | 0.43 | | | | |
| Residential location | Core cities | 0.25 | | | | |
| | Suburban | 0.28 | | | | |
| | Less urban | 0.47 | | | | |

To gain insight into how the social and environmental dimensions interact by geographical region we analysed the mean values of contact frequency and CO2 output by urban region in the Netherlands (Fig. 3). For each city region the mean values of the two variables were calculated and were placed on the two-dimensional space presented in Fig. 1. The axes represent the mean values for the entire sample. The figure also includes markings for the type of residential location (circles): core city, suburb or less urban. Seven regions have above average mean frequency of contact and below average mean CO2 output and therefore are placed in the upper right quadrant of high social and environmental sustainability. Nine regions have below average performance on both dimensions therefore are located in the bottom left quadrant. Three regions are located in the bottom right quadrant with higher than average social sustainability and lower than average environmental sustainability and three at the top left corner for the opposite case. Of the four largest city regions in the Netherlands, Rotterdam and Den Haag are in the top right quadrant, Utrecht is in the top left quadrant, indicating below average social sustainability and above average environmental sustainability. The largest city, Amsterdam, is located in the bottom left quadrant. The differences between the performance of family networks in individual city regions point at specific situational factors that we cannot analyse here but would merit further exploration. These differences might be explained for example to the local labour market and whether it is attractive for students and employers to migrate from outside the region, which might lead to greater travel distances between family members and thus to potentially lower social and environmental sustainability. Another explanation is related the relationship between the urban region and the surrounding countryside – if households tend to migrate from nearby rural areas and settle in the urban core then distances there might be longer compared to regions where no such migration is taking place (PBL, 2015).

For residential locations, suburban and less urban areas have higher than average social sustainability and higher than average environmental sustainability (top right), while in core cities both sustainability measures are below average. Suburban and less urban locations thus seem to enable positive synergy while core cities show a negative synergy on average.

## 5. Results of path analysis

We estimated the path analysis as shown in Fig. 2 using Mplus version 7. A path analysis is a category of Structural Equation Modelling (SEM) where all variables are observed (i.e. no latent variables are modelled). SEM is a methodology to model relationships between endogenous variables of different measurement scales. To allow for non-normality and because one of the endogenous variables, car use, is categorical, the model was estimated using the default WLSMV estimators (Muthén and Muthén, 2012). First, the model fit was examined (Table 2). Mplus provides four goodness-of-fit indices and for the assessment we followed the thresholds defined by Van Acker and Witlox (2010). Model 1 complies with three of the four thresholds, it only fails to comply with the TLI cut-off, and was thus determined satisfactory.

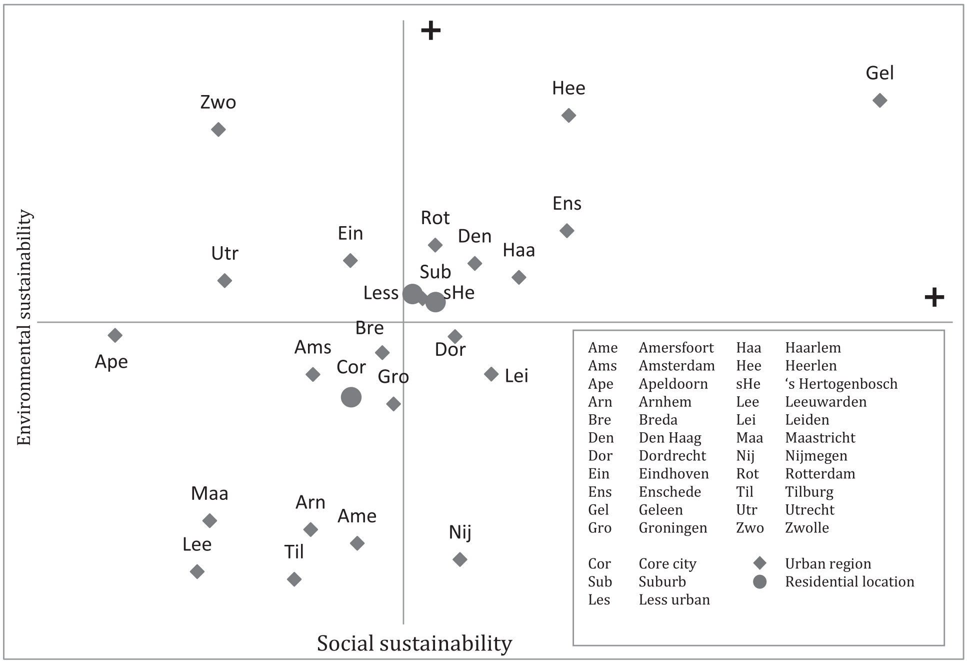


**Fig. 3.** Relative frequency of contact and CO2 output by geographical region and type residential location.

**Table 2**
Model fit indices.

| | | *Chi sq. (df)* | *p* | *RMSEA* | *CFI* | *TLI* |
|---|---|---|---|---|---|---|
| | Cut-off values (Van Acker and Witlox, 2010) | | < 0.05 | < 0.05 | > 0.95 | > 0.95 |
| (1) | Final model (see Fig. 2) | 36.367 (14) | 0.001 | 0.033 | 0.972 | 0.883 |
| (2) | Incl. car - > frequency | 36.660 (13) | 0.001 | 0.035 | 0.970 | 0.866 |
| (3) | Incl. frequency - > car | 36.658 (13) | 0.001 | 0.035 | 0.970 | 0.866 |

Following the modification suggestions provided by Mplus models 2 and 3 which include an additional direct link between car use and frequency were considered (see Fig. 2), however these models performed less well and did not provide any additional insight. The analysis therefore relates only to model 1.

Full results of the total effects are presented in Table 3. For the purpose of our analysis the most important aspect to consider is the comparison between the association of an exogenous variable with frequency of meetings and with total CO2 output. According to the definitions we applied this comparison enables us to assess family networks by their social and environmental sustainability performance. Five variables were found to have significant total effects with both frequency and CO2 output. Age was negatively associated with frequency and positively with CO2 output; youngest child between 12 and 17 (relative to no young children) was positively associated with frequency and negatively with CO2 output, the same as when the respondent"s mother lives alone; not owning a car (relative to owning one car) was negatively associated with both outcomes (less frequency and less CO2 output), the corollary is that relative to no cars owning one car is associated positively with the outcomes (more frequency and more CO2 output); living in a core city (relatively to living in a less urban area) is negatively associated with frequency and positively with CO2. These results demonstrate how different conditions and situations of the family network may lead to different relationships between the indicators for social and environmental sustainability.

By analysing the indirect effects we can understand how these relationships come about. In order to do that, we should first consider the relationships between the endogenous variables. Distance is, as expected, positively related to car use and negatively related to frequency of meetings. Distance, car use and frequency are positively related with CO2 output. This implies that beyond the expected positive direct effect on CO2 output, distance also has an indirect negative effect on CO2 output due to lower travel frequency and a positive indirect effect through the higher car use. Subsequently these complexities mediate the effects of the exogenous and endogenous variables. Table 4 illustrates the decomposition of the statistically significant total effects for the variables: distance, car ownership and residential location. For example, living in a core city has a total positive effect on CO2 output. This is so despite the negative indirect effect through distance on frequency – i.e. residents of core cities live farther away from their parents and thus see them less often. Two channels lead to the positive effect: one is the indirect effect via distance (core city residents live farther away) and the other, the indirect effect via car, which core city residents are more likely to use for these trips. A similar analysis could be applied for respondents without a car: as expected, they are less likely to use the car and see their parents less frequently, a relationship made visible by the indirect effect of no car on frequency via distance.

## 6. Opportunities and constraints for policy

To address our second research question, we now turn to the potential policy implications of the four types of relationships between social and environmental sustainability introduced above. The policy opportunities and constraints should be discussed in relation to the three main factors that construct our CO2 emissions indicator: distance, mode and frequency of travel. While the four types are a heuristic device, the variables and indicators define the context to which the potential policy instruments should relate to.

In Type 1 family network interaction is both relatively frequent and under our conceptualization environmentally sustainable. Variables that were associated with this pattern are: women (i.e. the observed contact is between a woman and her parents), families with young children and when the respondent"s contact is

**Table 3**
Total effects of endogenous and exogenous variables.

| | Distance | | Car use | | Frequency | | CO2 | |
|---|---|---|---|---|---|---|---|---|
| | Coeff. | s.e. | Coeff. | s.e. | Coeff. | s.e. | Coeff. | s.e. |
| ***Endogenous*** | | | | | | | | |
| Distance (ln km) | | | 0.611 | 0.041$^{***}$ | −0.350 | 0.024$^{***}$ | 1.395 | 0.204$^{***}$ |
| Car use | | | | | | | 2.099 | 0.210$^{***}$ |
| Frequency (ln days) | | | | | | | 0.780 | 0.111$^{***}$ |
| ***Exogenous*** | | | | | | | | |
| Female | −0.059 | 0.086 | −0.245 | 0.106$^{**}$ | 0.327 | 0.060$^{***}$ | −0.342 | 0.285 |
| Age | 0.027 | 0.007$^{***}$ | 0.011 | 0.008 | −0.010 | 0.005$^{**}$ | 0.054 | 0.022$^{**}$ |
| Has partner | 0.119 | 0.115 | 0.035 | 0.138 | −0.158 | 0.079$^{**}$ | 0.116 | 0.371 |
| Age youngest child (ref: no child 18-) | | | | | | | | |
| 0–5 | −0.091 | 0.128 | 0.125 | 0.163 | 0.220 | 0.090$^{**}$ | 0.308 | 0.434 |
| 6–11 | −0.141 | 0.130 | −0.242 | 0.161 | 0.159 | 0.092$^{*}$ | −0.581 | 0.438 |
| 12–17 | −0.552 | 0.139$^{***}$ | −0.407 | 0.165$^{**}$ | 0.273 | 0.093$^{***}$ | −1.413 | 0.457$^{***}$ |
| Resp. mother alone | −0.263 | 0.094$^{***}$ | −0.253 | 0.110$^{**}$ | 0.295 | 0.064$^{***}$ | −0.668 | 0.300$^{**}$ |
| Has siblings | 0.097 | 0.160 | −0.030 | 0.192 | −0.226 | 0.111$^{**}$ | −0.107 | 0.512 |
| Employed | 0.016 | 0.107 | 0.075 | 0.130 | −0.074 | 0.076 | 0.122 | 0.346 |
| *Car ownership (ref: 1 car)* | | | | | | | | |
| No car | 0.819 | 0.228$^{***}$ | −1.754 | 0.271$^{***}$ | −0.351 | 0.164$^{**}$ | −2.811 | 0.673$^{***}$ |
| 2+ cars | 0.098 | 0.085 | 0.272 | 0.104$^{***}$ | −0.016 | 0.060 | 0.696 | 0.282$^{**}$ |
| *Residential location* (ref: less urban) | | | | | | | | |
| Core | 0.240 | 0.100$^{**}$ | 0.343 | 0.127$^{***}$ | −0.122 | 0.069$^{*}$ | 0.959 | 0.339$^{***}$ |
| Suburb | −0.014 | 0.096 | 0.139 | 0.116 | −0.051 | 0.067 | 0.232 | 0.311 |

$^{*}$ < 0.01.
$^{**}$ < 0.05.
$^{***}$ < 0.01.

**Table 4**
Decomposition of effects for selected variables.

| Variable | Mediators | | Outcomes | |
|---|---|---|---|---|
| | *First* | *Second* | *Frequency* | *CO2* |
| **Distance** | – | – | −0.350$^{***}$ | 1.395$^{***}$ |
| | Car use | | | 1.281$^{***}$ |
| | Frequency | | | −0.273$^{***}$ |
| **No car** | – | – | ns | – |
| **(ref=1 car)** | Distance | | −0.286$^{***}$ | 1.142$^{***}$ |
| | Car use | | | −4.731$^{***}$ |
| | Frequency | | | ns |
| | Distance | Car use | | 1.049$^{***}$ |
| | Distance | Frequency | | −0.223$^{***}$ |
| **2+ cars** | – | – | ns | – |
| **(ref=1 car)** | Distance | | ns | ns |
| | Car use | | | 0.447$^{**}$ |
| | Frequency | | | ns |
| | Distance | Car use | | ns |
| | Distance | Frequency | | ns |
| **Core** | – | – | ns | – |
| **(ref=less urban)** | Distance | | −0.084$^{**}$ | 0.334$^{**}$ |
| | Car use | | | 0.413$^{*}$ |
| | Frequency | | | ns |
| | Distance | Car use | | 0.307$^{**}$ |
| | Distance | Frequency | | −0.065$^{**}$ |
| **Suburb** | – | – | ns | – |
| **(ref=less urban)** | Distance | | ns | ns |
| | Car use | | | ns |
| | Frequency | | | ns |
| | Distance | Car use | | ns |
| | Distance | Frequency | | ns |

ns – not significant;
$^{*}$ < 0.01.
$^{**}$ < 0.05.
$^{***}$ < 0.01.

with alone-living mother. These findings resonate with sociological theory on the central role women play in maintaining the family network (Mulder and Van der Meer, 2009; Rossi and Rossi, 1990; Silverstein et al., 2006) and the importance of informal support provision, such as child care provided by grandparents (Connidis, 2010), in explaining frequent contact between adult children and parents. Time-space geographic theory that points to the traditionally more complex activity schedules of women compared to men (Schwanen et al., 2008), highlights the crucial aspect of short distances as facilitator of frequent and support-related contact. Empirically, our model suggests that the short travel distances in this type are an important channel that contributes to the positive outcomes (in terms of social and environmental sustainability). The policy challenge derived from this analysis is to maintain the possibility for interaction among different age groups within those short distances. Processes of aging, which is expected to add need for informal support and frequent contact, and regional population decline in the periphery, caused by migration of young individuals to the urban core (Bontje and Musterd, 2012), place a threat on these networks' ability to sustain current patterns. The combination of the two might increase travel distances at a higher frequency. Another phenomenon related to aging is the increased car-mobility among older adults in the Netherlands, relative to previous older generations (PBL, 2013). This trend challenges the sustainable pattern of this type as well.

Type 2 represents the family networks which lack on both dimensions. Variables that were found relevant are mirroring the ones in Type 1: men, households without young children, when the respondent"s parents live together or when the respondent"s father lives alone. Also the variable age belongs to this group of cases, which suggests that with age respondents tend to live at a longer distance to their parents, have less contact, and overall travel in a less sustainable way.

As mentioned in the beginning the expectation was that the urban spatial structure is a facilitator of sustainable types of mobility. However, surprisingly, family networks where the adult child lives in a core city are interacting in a relatively low frequency and travel in an unsustainable way. A possible explanation for this finding is that from the perspective of adult children who live in highly urbanized areas in the Netherlands, their family is more dispersed relative to the family of adults in less urban areas (Mulder and Kalmijn, 2006). The policy goal for this type of networks should be to achieve a transition in at least one of the dimensions: either aim at enabling to increase the frequency of travel or at enabling to decrease the ecological footprint of the infrequent travel, or both. In particular, residents of core cities highlight the policy challenges. Within our framework the main constraint these families face is the relatively longer travel distances, which are influenced by a multitude of factors, like job and housing availability. Generating opportunities for families to live within relatively short distances could be a goal that addresses this constraint. For example, by offering adequate and affordable housing for parents in cities, an alternative to future long distance travel by children would be created. Alternatively, adult children would avoid long distance migration, and hence longer travel distances, if the supply of higher education and jobs would be expanded beyond large cities.

These results regarding residential environment should be interpreted cautiously. In this analysis we have taken the perspective of the adult child and the results are applicable to that case. One of the underlying processes that generated the travel distance for respondents who live in core cities, is their migration away from their parents. However, had we taken the perspective of the parent, we suspect that different results would emerge. Research has shown that children who grow up in cities (because their parents live there), tend to keep living in urbanised regions, or even stay within the same city (Blaauboer, 2011). If that is the case and the respondents were the parents of adult children, then we might have observed that in fact family networks in core cities are behaving in more sustainable ways.

Family networks of Type 3 and 4 are where trade-offs occur between frequency of travel and CO2 emissions. The variable that belongs to these types is car ownership: households with one car and two cars or more, meet relatively more than households with no car but have higher CO2 output. For Type 3 (car-less households) the main constraint on meetings seems to be the lack , or unaffordability, of adequate transport options. The key policy challenge seems to be enabling higher contact frequency without increasing car ownership. Family networks of Type 4 are constrained by the utility provided by the car: for CO2 output to decrease this type needs an alternative mode or technology that would provide the necessary conditions for high frequency contact without the harmful effects on the environment.

After identifying the challenges we now turn to address the opportunities for making travelling more sustainable. Within the limited framework of our model these lie at conditions related to low frequency of contact and the conditions related to high CO2 emissions. For the former these emerged to be in general terms households without a car (Type 4), residents of core cities (Type 2) and households that live at a long distance to the parental household (Type 2). For the latter these are households with one or more cars (Type 3), and, again, those living at long distance to their parents and those living in core cities. The potential improvements could be then identified sequentially: the first variable to be addressed is the mode of travel for a given distance and frequency. As shown by Type 4 households, car is currently central in supporting high contact frequency. Hence, improving environmental sustainability lies for example in replacing the car altogether, through investment in public transport. The path would also benefit Type 2 households, especially those residing in core cities, who already have relatively high accessibility to transit hubs. This solution has the potential to also create beneficial conditions regarding the second variable: frequency of contact for a given distance. Type 3 households lack an affordable alternative to the car, which they do not own, resulting in current low levels of contact frequency. For such an investment to be useful an intermediate step should be taken: ensuring that the proposed expansion of public transport services is performed in a way that indeed offers the utility, which until now was provided by automobility. Our model does not reveal the exact way in which cars are superior to other modes for the purpose of family meetings. Three advantages of cars were often mentioned: speed of travel, freedom of use and flexibility with respect to time and place (Schwanen and Lucas, 2011); the latter being particularly relevant to the unique spatial characteristics of family meetings when location of meetings are highly dispersed (Stern and Messer, 2009).

An alternative potential solution is the replacement of current high CO2 emission cars with other types of private vehicles like the electric car. This technological solution has often been adopted by policy makers as a goal (Kamruzzaman et al., 2015), but the applicability of this solution is in some contexts inadequate: residents of core cities are constrained by limited road infrastructure and parking space in cities. Households that currently do not own a car might face constraints with regards to the costs (Berkeley and Jarvis, 2012).

The third variable to be addressed is distance. Decreasing the distance between adult children and their parents is challenging as it depends on a range of conditions such as housing and job availability (Haas and Osland, 2014). These determine migration patterns of households and in turn, their ability to reside close to their important social contacts, especially in a multi-generational context. Interventions in housing markets and job markets aimed at providing affordable housing where jobs are concentrated and simulating job creations where people live, could perhaps enable more sustainable family networks as a side effect. In that case all else being equal - they would make it easier for family network members to locate closer to each other (e.g. parents could move to the core city because of more affordable housing, children could move to where their parents live because of more job availability).

This analysis does not address the full complexity of the issue. Opportunities for increasing frequency and decreasing car use might exist in domains beyond the scope of this paper. Frequency of contact might increase if, for example, time availability of households and families is addressed. Earlier analysis showed that the frequency of contact between adult children and their parents depends to some extent on the work arrangements of the child (Rubin, 2015). Non-standard work arrangements (introduction of ICT based work, flexible work hours) might increase or decrease time available for social activities and in turn have a great effect on contact frequency.

## 7. Conclusion

Developing a sustainable transport system is a multi-dimensional challenge (Litman, 2015). The goal of our analysis was to assess the social and environmental sustainability of an important activity: travelling for meetings between adult children and their parents. We argued that this activity differs from other types of travel in particular features that to some extent questions current thinking on sustainable mobility. Two simple indicators that measure these dimensions were used for an SEM analysis of unique data on family meetings: frequency of meetings and CO2 output.

Through the empirical analysis we were able to show the complex interaction between specific family characteristics and the two dimensions of sustainability. Four results stand out. First, the mediating role of distance. On the one hand distance had a negative effect on the indicator for social sustainability: frequency of meetings. On the other hand distance had a dual effect on the indicator for environmental sustainability: total CO2 output. It suppresses frequency of meetings, thus reduces CO2 output, but for a given frequency it increases CO2 output due to the increase in required travel and due to the increase in car use. Second, the dual role of car use was highlighted. Car ownership appeared to be a facilitator of frequent meetings, but in parallel also has a great impact on CO2 output. Third, living in a highly urban environment appeared to be negatively associated with both dimensions of sustainability, as respondents of core cities tend to meet less often with their parents and more often use the car for travelling. Distance played an important role in this outcome. Finally, we found arrangements that were associated with positive outcomes along the dimensions of sustainability. These were when the respondent was a woman, there were young children in the household and the respondent's parent was an alone-living woman. In these networks distance was shorter and car use was lower. The results that transpired from the statistical model fed an analysis of the possibilities for increasing sustainability – creating the conditions for frequent meetings, and reducing high CO2 output. These were identified to be mode change, technological innovation and distance reduction. However even within the prism of a single and particular type of social activity potential constraints were highlighted.

There are several limitations to this study that should be addressed in future studies. We acknowledge that the narrow focus of our sustainability indicators does no justice to the complexity of factors affecting location and mobility choices of households and the multiplicity of goals polices need to pursue. The policy implications are therefore limited to the factors addressed in the analysis. Additional and more sophisticated research is needed to assess the practical value of the suggested policy directions.

The most limitation is that a more comprehensive indicator for social sustainability of family meetings is needed. Our data did not allow us to include some crucial aspects, such as duration of meetings, type of meetings (whether they are a joint leisure activity, a practical support meeting or other) and the size of the travelling company. It could be that long travel distance and low frequency are compensated through longer meetings. Including duration in the analysis might have modified the position of some family networks within our framework.

The analysis presented here could also be extended to include other dimensions of interaction within family networks. For example, the subjective assessment of the quality of the relationship, the amount of support exchanged or the duration of visits, or frequency of contact with other family members. Our ability to make stronger policy recommendations was somewhat hindered by those data limitations. Future research might also expand on the relatively traditional way in which a family is framed in the current one (i.e. parents-children ties). In a context in which family-like networks are emerging and gaining importance, other type of ties might substitute traditional ones - a possibility that should be taken explicitly into account.

A further limitation of this analysis is the inclusion of travel mode in the model as a binary variable (car use – yes or no), rather than a categorical variable of the available modes (e.g. car, transit, active modes). This decision was taken due to technical limitations – neither Mplus version 7 nor other software packages (such as Stata version 13) support the estimation of models that include variables that act as both dependent and independent variables in them. Thus the reference category of “non-car” might confound effects. Variables that are associated with, for example, walking and transit in contradicting directions (a positive association with one mode and a negative with another), might end up showing an insignificant association in our model.

Finally, in the analysis we used a limited set of independent variables that could be expanded by future studies. While in our analysis we included variables that partly reflect the time budget of the individual (household composition, age of children and having a job), we did not have variables at our disposal that sufficiently capture household income. For instance, adult children with higher income might be able to finance formal care arrangements, which indirectly substitutes the need for face-to-face contact.

Another set of variables that is missing from our analysis is the one reflecting life-style variables with respect to car-use and travel (for the effect of lifestyle on family visits see: Van Acker et al., 2011) and variables that capture individual perceptions about the importance of family (see: Bengtson and Roberts, 1991). It is especially the latter type which could be useful for two main reasons: first, to explain distances between family members as an outcome partly related to the level of commitment individuals have towards their family, and second, to see how these perceptions and commitments translate into a different trade-off between travel and contact.

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## References


Banister, D., 2008. The sustainable mobility paradigm. Transp. Policy 15 (2), 73–80.

Banister, D., Anderton, K., Bonilla, D., Givoni, M., Schwanen, T., 2011. Transportation and the environment. Annu. Rev. Environ. Resour. 36, 247–270.

Bengtson, V.L., Roberts, R.E.L., 1991. Intergenerational solidarity in aging families: An example of formal theory construction. J. Marriage Fam. 53 (4), 856–870.

Berkeley, N., Jarvis, D., 2012. Low carbon mobility: opportunities and challenges for local economic development. Local Econ. 27 (7), 689–691.

Blaauboer, M., 2011. The impact of childhood experiences and family members outside the household on residential environment choices. Urban Stud. 48 (8), 1635–1650.

Bontje, M., Musterd, S., 2012. Understanding shrinkage in European regions. Built Environ. 38 (2), 153–161.

Brand, C., Preston, J.M., 2010. ‘60-20 emission’ – the unequal distribution of greenhouse gas emissions from personal, non-business travel in the UK. Transp. Policy 17 (1), 9–19.

Brand, C., Goodman, A., Rutter, H., Song, Y., Ogilvie, D., 2013. Associations of individual, household and environmental characteristics with carbon dioxide emissions from motorised passenger travel. Appl. Energy 104, 158–169.

Bucx, F., Van Wel, F., Knijn, T., Hagendoorn, L., 2008. Intergenerational contact and the life course status of young adult children. J. Marriage Fam. 70 (1), 144–156.

Cao, X., Mokhtarian, P.L., Handy, S.L., 2009. Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. Transp. Rev. 29 (3), 359–395.

Carrasco, J., Miller, E., Wellman, B., 2008. How far and with whom do people socialize?: Empirical evidence about distance between social network members. Transp. Res. Rec.: J. Transp. Res. Board 2076, 114–122.

Carrasco, J.A., Cid-Aguayo, B., 2012. Network capital, social networks, and travel: an empirical illustration from Concepción, Chile. Environ. Plan. A 44 (5), 1066–1084.

Connidis, I.A., 2010. Family Ties and Aging, 2nd ed. Sage Publications, Thousand Oaks, CA.

De Vos, J., Schwanen, T., Van Acker, V., Witlox, F., 2013. Travel and subjective well-being: a focus on findings, methods and future research needs. Transp. Rev. 33 (4), 421–442.

Dieleman, F.M., Dijst, M., Burghouwt, G., 2002. Urban form and travel behaviour: micro-level household attributes and residential context. Urban Stud. 39 (3), 507–527.

EC, 2009. Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the Effort of Member States to Reduce Their Greenhouse Gas Emissions to Meet the Community"s Greenhouse Gas Emission Reduction Commitments Up To 2020.

Grundy, E., Shelton, N., 2001. Contact between adult children and their parents in Great Britain 1986–99. Environ. Plan. A 33 (4), 685–698.

Haas, A., Osland, L., 2014. Commuting, migration, housing and labour markets: complex interactions. Urban Stud. 51 (3), 463–476.

Handy, S.L., 1996. Understanding the link between urban form and nonwork travel behavior. J. Plan. Educ. Res. 15 (3), 183–198.

Holden, E., Linnerud, K., 2011. Troublesome leisure travel: the contradictions of

three sustainable transport policies. Urban Stud. 48 (4), 1–20.
Holz-Rau, C., Scheiner, J., Sicks, K., 2014. Travel distances in daily travel and long-distance travel: what role is played by urban form? Environ. Plan. A 46 (2), 488–507.
International Energy Agency, 2009. Transport, Energy and CO2.
Kamruzzaman, M., Hine, J., Yigitcanlar, T., 2015. Investigating the link between carbon dioxide emissions and transport-related social exclusion in rural Northern Ireland. Int. J. Environ. Sci. Technol. 12 (11), 1–16.
Kowald, M., 2015. Personal networks in population wide network structure. In: Kowald, K.W., Axhausen, K.W. (Eds.), Social Networks and Travel Behaviour. Ashgate, pp. 99–152.
Lawton, L., Silverstein, M., Bengtson, V., 1994. Affection, social contact, and geographic distance between adult children and their parents. J. Marriage Fam. 56 (1), 57–68.
Lee, G.R., Netzer, J.K., Coward, R.T., 1994. Filial responsibility expectations and patterns of intergenerational assistance. J. Marriage Fam. 56 (3), 559–565.
Lelkes, O., 2006. Knowing what is good for you: empirical analysis of personal preferences and the "objective good". J. Socio – Econ. 35 (2), 285–307.
Litman, T., 2015. Well measured. Victoria, B.C.: Victoria Transport Policy Institute.
Martin, M., Westerhof, G.J., 2003. Do you need to have them or should you believe you have them? Resources, their appraisal, and well-being in adulthood. J. Adult Dev. 10 (2), 99–112.
Mulder, C.H., Kalmijn, M., 2006. Geographical distances between family members. In: Dykstra, P.A., Kalmijn, M., Knijn, T.C.M., Komter, A.E., Liefbroer, A.C., Mulder, C.H. (Eds.), Family Solidarity in the Netherlands. Dutch university Press, Amsterdam, pp. 43–61.
Mulder, C.H., Van der Meer, M.J., 2009. Geographical distances and support from family members. Popul. Space Place 15 (4), 381–399.
Muthén, L.K., Muthén, B.O., 2012. Mplus. The Comprehensive Modelling Program for Applied Researchers: User's guide, 5.
Neutens, T., Schwanen, T., Witlox, F., 2011. The prism of everyday life: towards a new research agenda for time geography. Transp. Rev. 31 (1), 25–47.
Nocera, S., Maino, F., Cavallaro, F., 2012. A heuristic method for determining $CO_2$ efficiency in transportation planning. Eur. Transp. Res. Rev. 4 (2), 91–106.
Rubin, O., Mulder, C.H., 2014. Who visits whom? The balance of intergenerational face-to-face contact, PAA Annual Meeting, Boston, 1–3 May 2014.
Otten, M.B.J.,'t Hoen, M.J.J., Den Boer, L.C., 2014. STREAM personenvervoer 2014. Studie naar transportemissies van alle modaliteiten, CE Delft.
PBL (Planbureau voor de Leefomgeving), 2013. Vergrijzing En ruimte: Gevolgen voor DE woningmarkt, vrijetijdsbesteding, mobiliteit En regionale economie. Den Haag.
PBL (Planbureau voor de Leefomgeving), 2015. De stad Als magneet, roltrap En spons: Bevolking ontwikkeling in stad En stadsgewest. Den Haag.
Pichler, F., 2006. Subjective quality of life of young Europeans. Feeling happy but who knows why? Soc. Indic. Res. 75 (3), 419–444.
Rossi, A.S., Rossi, P.H., 1990. Of Human bonding: Parent-Child Relations Across the Life Course. Aldine de Gruyter, New York.
Rubin, O., 2015. Contact between parents and adult children: the role of time constraints, commuting and automobility. J. Transp. Geogr. 49, 76–84.
Rubin, O., Mulder, C.H., Bertolini, L., 2014. The determinants of mode choice for family visits – evidence from Dutch panel data. J. Transp. Geogr. 38, 137–147.
Scherpenzeel, A., Das, J.W.M., 2010. 'True' longitudinal and probability-based internet panels: evidence from the Netherlands. Soc. Behav. Res. Internet.: Adv. Appl. Methods Res. Strateg., 77–103.
Schwanen, T., Lucas, K., 2011. Understanding auto motives. In: Lucas, K., Blumenberg, E., Weinberger, R. (Eds.), Auto Motives: Understanding Car Use Behaviours. Emerald, Bingley, pp. 1–38.
Schwanen, T., Dieleman, F.M., Dijst, M., 2001. Travel behaviour in Dutch monocentric and policentric urban systems. J. Transp. Geogr. 9 (3), 173–186.
Schwanen, T., Kwan, M.P., Ren, F., 2008. How fixed is fixed? Gendered rigidity of space–time constraints and geographies of everyday activities. Geoforum 39 (6), 2109–2121.
Silverstein, M., Gans, D., Yang, F.M., 2006. Intergenerational support to aging parents the role of norms and needs. J. Fam. Issues 27 (8), 1068–1084.
Statistics Netherlands, 2010. ⟨http://statline.cbs.nl⟩.
Stern, M.J., Messer, C., 2009. How family members stay in touch: a quantitative investigation of core family networks. Marriage Fam. Rev. 45 (6–8), 654–676.
Van Acker, V., Witlox, F., 2010. Car ownership as a mediating variable in car travel behaviour research using a structural equation modelling approach to identify its dual relationship. J. Transp. Geogr. 18 (1), 65–74.
Van Acker, V., Mokhtarian, P., Witlox, F., 2011. Going soft: on how subjective variables explain modal choices for leisure travel. Eur. J. Transp. Infrastruct. Res. 11 (2), 115–146.
Van Gaalen, R.I., Dykstra, P.A., Flap, H., 2008. Intergenerational contact beyond the dyad: the role of the sibling network. Eur. J. Ageing 5 (1), 19–29.
Zandvliet, R., Bertolini, L., Le Clercq, F., 2005. Sustainability in a networked urban world: an approach for dealing with the space–time redistribution of environmental costs and economic benefits. Plan. Pract. Res. 20 (3), 279–295.
Zito, P., Salvo, G., 2011. Toward an urban transport sustainability index: an European comparison. Eur. Transp. Res. Rev. 3 (4), 179–195.