Linear, non-linear, bi-directional? Testing the nature of the relationship between mobility and satisfaction with life

Alexa Delbosc[1] · Maarten Kroesen[2] · Bert van Wee[2] · Mathijs de Haas[3]

Abstract

Travel is one of the most important facilitators of life and has been widely acknowledged as a prerequisite for economic and social activity. Research developing in recent decades has found that limitations to mobility and accessibility can reduce satisfaction with life. To date, research in this field assumes a linear and one-way relationship between the two—i.e. that 'more mobility' results in 'more life satisfaction'. Yet diminishing marginal returns on happiness are found in many related fields such as economics, and there is always the possibility that happier people travel more than unhappy people. To the authors' knowledge, this paper presents the first attempt to look for evidence of a non-linear relationship between mobility (measured as trip-making) and life satisfaction, and the first to test the direction of causality between the two factors. It uses a sample of some 1500 adults in the Netherlands Mobility Panel. Linear and segmented regression models were used to associate trip-making with satisfaction with life, when controlling for income, age, self-rated health and other demographics. Counter to expectations, five different model specifications suggest that the relationship between trip-making and satisfaction with life is linear. Furthermore, a structural equation model found that the relationship between mobility and satisfaction could run in either direction. This study questions many of the assumptions made about the relationship between transport and subjective well-being. Given the increasing prominence of this topic, much research is needed to further explore these complex relationships.

Keywords Transportation · Mobility · Satisfaction with life · Well-being

✉ Alexa Delbosc
Alexa.delbosc@monash.edu

[1] Department of Civil Engineering, Monash University, 23 College Walk, Clayton, VIC 3800, Australia

[2] Faculty of Technology, Policy and Management, TU Delft, Building 31. Jaffalaan 5, 2628 BX Delft, The Netherlands

[3] KiM Netherlands Institute for Transport Policy Analysis, Bezuidenhoutseweg 20, 2594 AV The Hague, The Netherlands

Introduction

Travel is one of the most important facilitators of life and has been widely acknowledged as a prerequisite for economic and social activity. Research linking transport, social exclusion and well-being has developed through a number of leading studies over the last decade. Ultimately, these studies find that limitations to mobility or accessibility, particularly when combined with social exclusion, result in a reduced quality of life (Banister and Bowling 2004; Spinney et al. 2009; De Vos et al. 2013; Delbosc and Currie 2018; Mokhtarian 2019).

However to date, these studies model a linear relationship between mobility indicators and well-being, implicitly assuming that 'more travel' results in 'more life satisfaction' (Delbosc and Currie 2018). Yet there is likely a non-linear effect, after which more journeys do not provide the same benefits to well-being. Diminishing returns on happiness are commonly observed in other fields; for example beyond poverty levels, high income does not 'buy happiness' (Kahneman and Deaton 2010). Similar non-linear effects are found in the transport and activity-participation fields: increasing destination accessibility provides diminishing marginal benefits (Maat et al. 2005), longer activity participation is associated with reduced enjoyment (Ravulaparthy et al. 2016) and holidaymaking provides diminishing returns on happiness (Kroesen and Handy 2014). However, to date the research linking mobility and well-being has assumed that the relationship is linear (Mollenkopf et al. 2005; Archer et al. 2013; Morris 2015). To our knowledge no-one has yet considered whether this relationship might be non-linear.

Furthermore, the theoretical and empirical models of transport and well-being almost exclusively assume a single direction of causality: that mobility or access influences well-being. A few researchers have started to question this assumption, pointing out that happier people may travel more than unhappy people (Morris 2015). Yet to date only one study has found some evidence that happier people are more likely to engage in travel than unhappy people (Morris and Guerra 2015).

In this paper, we look for evidence of a non-linear relationship between mobility and well-being. We also directly explore the direction of causality between mobility and well-being by testing whether the relationship is uni-directional or bi-directional.

We explore these relationships using the Netherlands Mobility Panel (MPN), a household travel survey distributed to approximately 2000 households. Each member of the household filled out a travel diary documenting all trips taken across 3 days as well as information about demographics and self-rated health. An additional supplement, completed by 1621 adults, included a Dutch translation of the Satisfaction with Life Scale (SWLS) (Diener et al. 1985).

Research context

What makes people happy?

Many things influence our satisfaction with life (which is also referred to as subjective well-being or simply happiness). Around half of our day-to-day happiness is determined by genetic and personality influences that are stable and generally outside of our control (Lyubomirsky et al. 2005). The other half of life satisfaction is determined by a range of factors; the most significant of these are meaningful social relationships, health and

income. Having strong social support and good health both have a positive influence on well-being (Okun et al. 1984; Cohen 2004). Income has diminishing returns on life satisfaction (a point we will return to), although living in poverty or being unemployed both have a significant negative effect on life satisfaction (Clark and Oswald 1994; Myers 2000).

Transport can facilitate all three of these essential components of happiness. In recent years, various researchers have set out hypothesized relationships between transport and well-being that illustrate how mobility or accessibility facilitates good health, social relationships and income (see for example Delbosc 2012; De Vos et al. 2013; Reardon and Abdallah 2013; Mokhtarian 2019). This perspective focuses on the benefits of mobility as a derived demand for activities that maintain positive well-being. It has spurred a wealth of studies linking well-being to activity participation and time use (Spinney et al. 2009; Archer et al. 2013; Morris 2015). Moreover, others have argued that mobility provides benefits in its own right, beyond its role as a derived demand (Mokhtarian and Salomon 2001; Metz 2008).

Note that this field of research examines how mobility (trip-making) fulfills the needs and wants of people, measured through subjective well-being. This is also called the 'hedonic' component of well-being. This is distinct from 'eudemonic' well-being, or the capability to live a fulfilling and meaningful life (Ryan and Deci 2001). Some have theorized that eudemonic well-being is facilitated by accessibility, which provides motility or the potential ability to travel (Delbosc and Currie 2018; Shliselberg and Givoni 2018). However the majority of empirical research has focused on the relationship between mobility and hedonic well-being (Delbosc and Currie 2018). Morris (2019) provides a recent exception, finding a relationship between out-of-home activity participation and eudemonic affect (although the models are not presented in the paper).

Thus far, most of the research linking transport to well-being has implicitly or explicitly made two assumptions: that the relationship is linear and that it is uni-directional (with transport influencing well-being). The next two sections explore the underpinnings of these assumptions and preliminary evidence that they may not always be correct.

How much mobility is enough to make you happy?

To the authors' knowledge no studies have directly linked trip-making to well-being. Mobility is instead quantified through measuring travel time (Archer et al. 2013; Morris 2015), number or duration of out-of-home activities (Banister and Bowling 2004; Spinney et al. 2009; Archer et al. 2013; Ravulaparthy et al. 2013; Morris 2015) or a combined index of mobility indicators (Mollenkopf et al. 2005). To the best of our knowledge, this paper is the first to empirically link trip-making to subjective well-being.

Furthermore, the papers that model the relationship between mobility indicators and well-being tend to use specifications that theorize the relationship as linear (Mollenkopf et al. 2005; Archer et al. 2013; Morris 2015). The implication is that as mobility increases, well-being will increase proportionally. Yet it can also be theorized that mobility may have diminishing marginal returns on happiness. This hypothesis has not yet been tested directly, although there is indirect evidence that the relationship may be non-linear.

Such evidence can be found, for example, in research focused on modelling people's engagement in (in-home and/or out-of-home) discretionary activities. Within this area researchers develop advanced utility-based models to estimate the effects of personal and activity-related characteristics on the observed duration of activities (see for example Bhat et al. 2006; Ettema et al. 2007; Kapur and Bhat 2007; Spissu et al. 2009; Pinjari and

Bhat 2010). In the formulation of these models it is common to include so-called satiation-parameters, which capture the assumed diminishing marginal returns associated with increasing time spent on a certain activity. For example, Spissu et al. (2009) used this type of model to assess the effects of various socio-demographic characteristics on the time spent on six types of out-of-home discretionary activities using data on the weekly time allocated to these activities. With respect to the satiation-parameters the authors found that social and cultural activities had relatively low satiation effects, while the highest satiation effect was observed with respect to sports activity. Hence, engagement in sport activities was associated with larger diminishing marginal returns compared to engagement in social or cultural activities, which seems to be an intuitively plausible result.

All in all, these models provide evidence that satiation effects occur with respect to engagement in discretionary activities, suggesting that such effects may also exist with regard to mobility behavior (trip making). However, it should be remembered that the models developed in this field do not include any direct measurements of well-being or satisfaction; instead utility is inferred from the observed choices of individuals. This means that satiation effects can only be 'proven' insofar as the models with satiation parameters provide better a fit to the data (i.e. the observed choices) compared to models without such effects.

Only two studies could be found in the extant literature which used direct measurements of well-being to reveal satiation effects of activity participation (Kroesen and Handy 2014; Ravulaparthy et al. 2016). Ravulaparthy et al. (2016) conducted a diary survey in which elderly respondents were asked to report the type, time of day, duration and well-being associated with all activities they had been engaged in during the period covered by the diary. The authors found a negative correlation between the duration of an activity episode and the happiness associated with that episode, which they took as evidence of satiation. Hence, more time spend on the activity led to a decrease in the well-being associated with the activity (ceteribus paribus).

Further evidence of satiation effects were found in Kroesen and Handy (2014). They assessed the relationship between respondents' annual holiday frequency, on the one hand, and their (overall level of) well-being, on the other. Going from 0 to 1, 1 to 2 and 2 to 3 holidays per year, significant but diminishing increases in the two considered well-being measures were observed, and after 3 holidays the increases became insignificant, clearly indicating a satiation/threshold effect.

Do happy people travel more?

To date, most of the research on transport and well-being has assumed or imposed a one-way relationship whereby travel or activity participation influences well-being. This has been expressed both in theoretical models of the relationship (e.g. Ettema et al. 2010; Delbosc 2012) and in the assumptions underpinning cross-sectional, empirical models (e.g. Mollenkopf et al. 2005; Archer et al. 2013; Morris 2015).

Yet several authors have highlighted the problems with this assumption, acknowledging that we cannot exclude the possibility that happier people could be more likely to travel than unhappy people (Reardon and Abdallah 2013; Morris 2015). De Vos and Witlox (2017) discuss in great depth the potentially bi-directional relationship between travel satisfaction and long-term well-being (although this is a slightly different question to whether travel per se has a bi-directional relationship with well-being). A few authors have updated

their theoretical frameworks to account for the possibility that well-being may influence mobility either directly (through increased activity) or indirectly (through their orientation toward travel or residential location choice) (De Vos et al. 2013; Delbosc and Currie 2018).

There are possible psychological underpinnings for this effect. The broaden-and-build theory of positive psychology suggests that happier people broaden their attention and thinking, which builds personal resources and further fuels greater well-being (Fredrickson 2004). To date, the evidence of 'broadening' effects have focussed on attention and cognition (Conway et al. 2013), yet it could be theorised that happier people may 'broaden' their travel horizon to encompass more activities. These additional activities may build additional skills and social resources, which reinforce further life satisfaction and flourishing.

However, little has been done empirically to explore the potentially bi-directional relationship between mobility and well-being. Ravulaparthy et al. (2016) explicitly bypassed this assumption by jointly exploring the relationship between out-of-home activities and satisfaction through correlation. To the authors' knowledge, only Morris and Guerra (2015) found some evidence that happier people are more likely to travel than the unhappy, although they acknowledge that this relationship is likely to be complex. Furthermore, this study was not deliberately testing the direction of causality but rather came across the possibility by comparing OLS models (which captures variation in affect by activity across travelers) with fixed-effect models (which account for individual-specific variation in total affect).

In summary, there is quite some evidence that satiation effects (or at least diminishing returns) occur with repect to engagement in various (out of home) activities, yet such effects have not been explored with respect to general mobility behavior. Furthermore, although multiple researchers have acknowledged that the relationship between travel and well-being may be bi-directional only one empirical study has indirectly explored his possibility (Morris and Guerra 2015). Hence, in addition to empirically examining the link between trip making and well-being, this paper will explore whether satiation occurs in this relationship and whether the relationship is uni-directional or bi-directional. This paper will use linear and segmented regression analyses to test whether the relationship between mobility and satisfaction with life is linear or not and structural equation modelling to test the direction of the relationship.

Methodology

The Netherlands

The Netherlands is a relatively small (41,543 km^2) country with over 17 million inhabitants, and consequently it is a densely populated country. It has a dense motorway and railway network and is famous for its high quality cycling infrastructure. According to the World Economic Forum (2018) the country is ranked fourth worldwide with respect to the quality of (transport and other) infrastructure. Spatial planning policies enforcing compact development have been in place since the 1960s (Ministry of VROM 1991). Despite higher levels of congestion in the densely populated western part of the country (in which the cities of Amsterdam, The Hague, Rotterdam and Utrecht are situated), accessibility of jobs is quite high. Land-use differences largely explain difference in accessibility more than differences in transport infrastructure (PBL 2014). Because all of the major cities are relatively dense and small (below 1 million inhabitants), many destinations are accessible within short distances for many people.

Netherlands mobility panel

In this study, we use data from the fifth wave of the Netherlands Mobility Panel (MPN). The MPN is an annual household panel that was set up to study the short-run and long-run dynamics in the travel behaviour of Dutch individuals and households. The MPN started in 2013 and consists of approximately 2000 complete households. Before households enter the panel, an adult household member is asked to fill out a screening questionnaire. The screening questionnaire is designed to gather basic information about the household and present information about the design and goal of the MPN. Each year after entering the panel, between September and November, an adult household member fills out a household questionnaire and all household members of at least 12 years old are asked to fill out an individual questionnaire and complete a 3-day online travel diary, including both weekdays and weekends.[1] The 3 days of trips provides a much richer representation of an individual's travel behavior than most studies of transport and well-being, which are generally restricted to a single day's travel or time use (e.g. Spinney et al. 2009; Archer et al. 2013; Morris 2015).

The questionnaires provide extensive information about (changes in) personal- and household characteristics. More information about the MPN can be found in Hoogendoorn-Lanser et al. (2015). Recruitment was conducted by a field work agency with ISO 26362 certification for the ethical conduct of market, opinion and social research. Data privacy standards comply with the EU General Data Protection Regulation.

Besides the yearly questionnaires and the 3-day travel diary, the MPN is used to study specific topics by means of additional questionnaires throughout the year. In June 2018, an additional questionnaire was sent out to 1621 adult MPN respondents which included the Satisfaction with Life Scale (Pavot and Diener 2009) to measure subjective well-being. This sub-sample of MPN respondents was used in the present analysis.

To limit the bias in the diary data, respondents who are suspected to report no trips while they actually did make trips are removed from the sample. These so-called "soft refusers" are identified using three different methods, as described in De Haas et al. (2017). Identification is done based on attrition, questionnaire response behavior and a logit model that estimates the chance of a respondent leaving the house on a given day. With a combination of these methods, between 5% and 10% of respondents per wave are found to be at high risk of exhibiting soft refusal. However, as this study used data from the most recent wave, information about attrition was not yet available. Based on the other two methods, 1.3% of respondents in the sample were removed as they were suspected to be soft refusers. The final sample size was 1558 respondents.[2]

Variables examined

The variable of primary interest was the number of trips undertaken over the 3 days of the MPN travel diary. Trips undertaken as part of a respondent's employment duties (such as making deliveries or driving a bus) were excluded from analysis.

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[1] Non-commute trip rates are very similar between weekdays and weekends in the Netherlands. Nonetheless, we ran a version of the following analyses using 'adjusted' trip rates for the number of weekend days across the 3-day sample. Results did not differ so the non-adjusted trip rates were used.

[2] The dataset used in this analysis is publicly available at https://doi.org/10.26180/5c6df45289d38.

The MPN also provided a range of potential control variables that may have a significant impact on happiness. The control variables used were as follows:

- Self-rated health (on a five-point scale from 'bad' to 'excellent').
- Household income (aggregated to four categories including 'don't know').
- Age (aggregated to four categories).
- Gender.
- Living alone.
- Being a single parent.
- Being economically active (employed or volunteering).

The final three control variables acted as a proxy for 'meaningful social relationships', as this component of well-being was not measured directly in the MPN. Living alone, being a single parent and not being economically active were used to represent having threats to meaningful social relationships.

Finally, the dependent variable was the Satisfaction with Life Scale (SWLS) (Diener et al. 1985). Participants rated the following five statements on a scale from 1 (strongly disagree) to 7 (strongly agree). The MPN is administered in Dutch; the English translation is given below.

1. In most ways my life is close to my ideal (In de meeste gevallen is mijn leven bijna ideaal).
2. The conditions of my life are excellent (Mijn levensomstandigheden zijn uitstekend).
3. I am satisfied with my life (Ik ben tevreden met het leven).
4. So far I have gotten the important things I want in life (Tot nu toe heb ik de belangrijkste dingen in mijn leven bereikt).
5. If I could live my life over, I would change almost nothing (Als ik mijn leven opnieuw kon beginnen, dan zou ik bijna niets veranderen).

For the regression analysis these five items were combined into one scale by averaging, as they measure a unidimensional underlying construct (Cronbach's Alpha = .879). In the structural equation model these five items were used as indicators for the latent variable 'satisfaction with life.'

Testing for a non-linear relationship

Four linear regression models were formulated as a two-step regression predicting the average Satisfaction with Life Scale (SWLS) rating. The first step included all available control variables that are likely responsible for life satisfaction (self-rated health, household income, age, gender, living alone, being a single parent and being economically active). These variables operationalised the three factors have the greatest impact on individual life satisfaction: meaningful social relationships, health and income (Okun et al. 1984; Myers 2000; Cohen 2004).

The number of trips taken over the 3-day travel diary was added in the second block to test whether mobility increases the predictive validity of the models. Trips were operationalized in four ways:

- Model 1: All trips undertaken over 3 days.

- Model 2: Commuting and non-commuting trips undertaken over 3 days.
- Model 3: Square root of non-commuting trips undertaken over 3 days.
- Model 4: Natural log of non-commuting trips undertaken over 3 days.

Both commute and non-commute trips were examined as the literature suggests that discretionary out-of-home activities (especially leisure and socializing) are more important for maintaining positive well-being (Kahneman et al. 2004; Ravulaparthy et al. 2013, 2016). In contrast, commute trips are usually found to be neither satisfying nor rewarding (De Vos et al. 2013), and their effect on well-being is a matter of commute length rather than number of trips (Chatterjee et al. 2019).

Models 1 and 2 establish whether there is a significant linear relationship between mobility and SWLS. Models 3 and 4 provide an initial test to determine whether trips provide diminishing returns on satisfaction with life. If mobility provides diminishing returns on well-being, we expect models 3 and 4 to show a better fit than models 1 and 2.

For each set of regression analyses, the models were tested for collinearity and autocorrelation of errors. There was no evidence of collinearity and Durban-Watson measure of error-auto-collinearity was acceptable (1.89).

A further test was conducted to determine if the relationship between transport and well-being was non-linear. We conducted a segmented regression with a Davies test to check whether the regression parameter for trips was constant across its range of values. If the Davies test is significant, the 'Segmented' package in R can identify where and how much the slope changes (Davies 1987; Muggeo 2008).

Testing for a bi-directional relationship

As discussed in the literature review, another possibility is that the relationship between mobility and well-being is bi-directional; people who are satisfied with their life may be more inclined to make discretionary trips. To explore this possibility, structural equation modelling (SEM) was chosen as an appropriate method to test three possible relationships: 1) mobility influences well-being, 2) well-being influences mobility or 3) the two variables simultaneously influence each other.

Structural equation modelling is a modelling technique that tests hypothesized causal relationships between multiple variables and is becoming widely used in travel behavior research (Golob 2003). Unlike linear regression, a SEM can model several endogenous (dependent) variables in a single model as well as correlations between exogenous (independent) variables. It can also model latent variables that cannot be observed directly (such as 'satisfaction with life') using confirmatory factor analysis of observed variables (such as survey scale responses). Finally, SEM allows the modelling of simultaneous, non-recursive relationships between two endogenous variables (in this case, mobility and satisfaction with life). This method has been used recently in transport to test the direction of the relationship between social media use and travel for social purposes (Delbosc and Mokhtarian 2018).

Although parsimonious model identification can be a significant issue in SEM, we chose to specify a model that includes a representation of each variable tested in the regression models. However, to take advantage of the strengths of SEM we also included correlations between exogenous variables where these correlations were significant. Also note that whenever a SEM includes a non-recursive feedback loop, at minimum one of the endogenous variables must have a unique identifier (Kline 2015). For this model, we began by

regressing all of the control variables only against SWLS (as a parallel to the regression models). Modification indices suggested that 'age' was also significantly associated with trip-making, but the other five control variables were only regressed against SWLS, more than meeting the baseline requirements for non-recursive model specification.

A range of goodness-of-fit indices should be applied to SEM to determine absolute and incremental fit (Holmes-Smith et al. 2006). For this analysis, we chose two traditional measures of absolute fit (root mean square error approximation, RMSEA, and goodness of fit index, GFI) and two measure of incremental fit (adjusted goodness of fit index, AGFI, and Tucker-Lewis index, TLI). For GFI, AGFI and TLI the accepted threshold is 0.90 or higher; for RMSEA values below 0.05 are ideal but up to 0.08 are acceptable (Byrne 2001).

When interpreting an SEM, the relationship between indicator variables and latent variables can be interpreted as factor loadings in a Principle Components Analysis; relationships between exogenous and endogenous variables (or between two endogenous variables) are interpreted as standardized regression weights (Byrne 2001).

Is there a non-linear relationship between mobility and well-being?

Table 1 provides the results of the regressions predicting SWLS. All models were statistically significant; the adjusted R^2 values suggest that around 21% of the variance in SWLS was captured by the model. This is within the range of typical values found in the transport and well-being literature (see for example Bergstad et al. 2012; Choi et al. 2013; Morris 2019).

In each model, control variables acted as expected from the literature. Self-rated health had the largest association with SWLS, followed by household income. Being aged over 60 and working or volunteering were both associated with higher SWLS; living alone or being a single parent was associated with lower SWLS. Gender did not have a significant effect on well-being.

In each model, adding trips in step 2 significantly improved the model fit (as measured by the F-change statistic), although the increase in fit was modest (about 1–1.5% increase in predictive power). The fit of all four models was quite consistent, as are the magnitude of the control parameters, suggesting that the relationship between mobility and well-being is fairly stable regardless of the selection and mathematical specification of the number of trips. In general, the relationship between trip-making and well-being is small (standardized coefficients between .06 and .07) but greater than the relationship between well-being and being a single parent (− .05).

Model 2 suggests that the relationship between mobility and well-being is carried by non-commute trips (standardized coefficient 0.07), whereas commute trips have no significant relationship to well-being. The effect of having a job or volunteering is significant (0.10–0.11), not the number of commute trips that results from this job.

If the relationship between transport and well-being is non-linear, then models 3 and 4 should show a better fit and the coefficients for trips should be higher than in the linear models. Instead, we found no meaningful difference in model fit between the four models, and the coefficients for the square root and natural log of non-commute trips were actually lower (0.06) than in the linear model of non-commute trips (0.07). This does not support the hypothesis that the relationship between the two is non-linear.

This finding is visualized in Fig. 1, which graphs the (linear) number of non-commute trips against the unstandardized predicted value for SWLS (controlling for all other

Table 1 Regressions predicting satisfaction with life scale

	Model 1 All trips (linear)		Model 2 Commute versus non-commute trips (linear)		Model 3 Non-commute trips (sq. root)		Model 4 Non-commute trips (natural log)	
	B (St. error)	Beta	B (St. error)	Beta	B (St. error)	Beta	B (St. error)	Beta
Constant	5.158 (0.133)		5.162 (0.133)		5.115 (0.138)		5.116 (0.140)	
Health excellent	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Health very good	−0.192 (0.093)	−0.07*	−0.195 (0.093)	−0.07*	−0.195 (0.093)	−0.07	−0.195 (0.093)	−0.07
Health good	−0.498 (0.087)	−0.22**	−0.500 (0.087)	−0.22**	−0.501 (0.087)	−0.22**	−0.502 (0.087)	−0.22**
Health mediocre	−1.127 (0.104)	−0.36**	−1.138 (0.105)	−0.36**	−1.136 (0.104)	−0.36**	−1.136 (0.104)	−0.36**
Health bad	−1.554 (0.176)	−0.23**	−1.567 (0.176)	−0.23**	−1.569 (0.176)	−0.23**	−1.573 (0.176)	−0.23**
HH inc. low (<27,000)	ref	ref	ref	ref	ref	ref	ref	ref
HH inc. middle (27,000 to <67,000)	0.195 (0.073)	0.09**	0.199 (0.073)	0.09**	0.198 (0.073)	0.09**	0.198 (0.073)	0.09**
HH inc. high (≥67,000)	0.445 (0.096)	0.14**	0.450 (0.096)	0.14**	0.450 (0.096)	0.14**	0.450 (0.096)	0.14**
HH inc. don't know	0.304 (0.093)	0.09**	0.304 (0.093)	0.09**	0.306 (0.093)	0.09**	0.306 (0.093)	0.09**
Age 18–24	ref	ref	ref	ref	ref	ref	ref	ref
Age 25–39	0.032 (0.057)	0.02	0.019 (0.057)	0.01	0.022 (0.057)	0.02	0.023 (0.057)	0.02
Age 40–59	−0.072 (0.054)	−0.06	−0.087 (0.055)	−0.08	−0.084 (0.055)	−0.07	−0.084 (0.055)	−0.07
Age 60+	0.203 (0.056)	0.17**	0.179 (0.058)	0.15**	0.185 (0.057)	0.16**	0.187 (0.057)	0.16**
Gender (female)	0.047 (0.026)	0.04	0.042 (0.026)	0.04	0.042 (0.026)	0.04	0.043 (0.026)	0.04
Employed or volunteering	0.120 (0.033)	0.10**	0.132 (0.033)	0.11**	0.127 (0.032)	0.10**	0.126 (0.032)	0.10**
Lives alone	−0.325 (0.070)	−0.11**	−0.328 (0.070)	−0.12**	−0.329 (0.070)	−0.12**	−0.330 (0.070)	−0.12**
Single parent	−0.266 (0.121)	−0.05*	−0.267 (0.120)	−0.05*	−0.267 (0.120)	−0.05*	−0.267 (0.120)	−0.05*
Number of trips	0.013 (0.005)	0.06*						
Number of commute trips			−0.006 (0.013)	−0.01				
Number of non-commute trips			0.014 (0.005)	0.07**				
Square root of non-commute trips					0.061 (0.022)	0.06**		
Natural log of non-commute trips							0.081 (0.031)	0.06*
R	0.462		0.463		0.462		0.462	

Table 1 (continued)

	Model 1 All trips (linear)		Model 2 Commute versus non-commute trips (linear)		Model 3 Non-commute trips (sq. root)		Model 4 Non-commute trips (natural log)	
	B (St. error)	Beta	B (St. error)	Beta	B (St. error)	Beta	B (St. error)	Beta
R^2 adjusted (Step 1)	0.203		0.203		0.203		0.203	
R^2 adjusted (Step 2)	0.205		0.206		0.206		0.205	
ANOVA F	27.84		26.27		28.19		28.14	
F change	6.51		4.48		7.25		6.54	

** indicates coefficient is statistically significant at $p < .01$; * indicates significance at $p < .05$. All models are statistically significant as was the change in F test
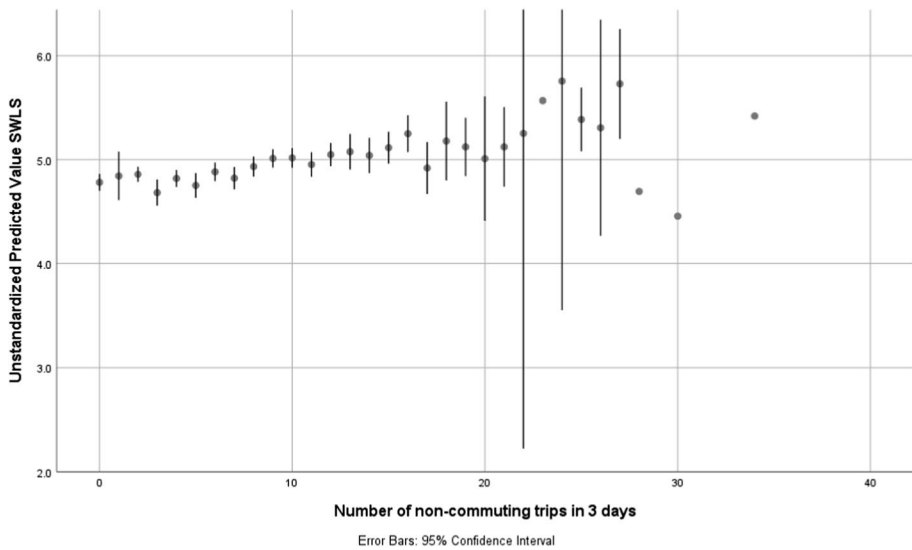
Fig. 1 Unstandardised predicted values of Satisfaction with Life versus non-commute trips

variables). Although not perfectly linear, there is no evidence that the effect of trips on SWLS tapers off at higher values.

Finally, we conducted a segmented regression with a Davies test to check whether the regression parameter for non-commuting trips was constant across its range of values (Davies 1987, Muggeo 2008). The Davies test returned a non-significant result (*p* value = 1) strongly suggesting that the slope of non-commuting trips was linear.

Is there a bi-directional relationship between mobility and well-being?

Structural equation models were specified to somewhat replicate the linear regression models using appropriate indicators for control variables. The only control variable not included was gender, as this variable was not significant in any regression or SEM models. 'Non-commute trips' was selected as the indicator of mobility as the regressions showed that these trips were the most strongly associated with life satisfaction. Three models were run testing alternative relationships between trip-making and SWLS:

- Model A: More non-commute trips increase satisfaction with life.
- Model B: People with higher satisfaction with life make more non-commute trips.
- Model C: Both relationships exist simultaneously.

Table 2 presents the overall model fit for each of these models. All three models comfortably meet all four goodness-of-fit indicators; Models A and B have identical fit measures and Model C is near-identical.

In all three model specifications, the five survey scales that make up the Satisfaction with Life Scale were all strongly significant indicators of the underlying construct of 'life satisfaction', with weightings between .63 and .87. Modification indices suggested that age

Table 2 Fit measures for structural equation models

	Model A Trips→SWLS	Model B Trips←SWLS	Model C Trips←>SWLS	Acceptable threshold
GFI	.964	.964	.964	> .900
AGFI	.941	.941	.940	> .900
TLI	.924	.924	.922	> .900
RMSEA	.063	.063	.064	< .080
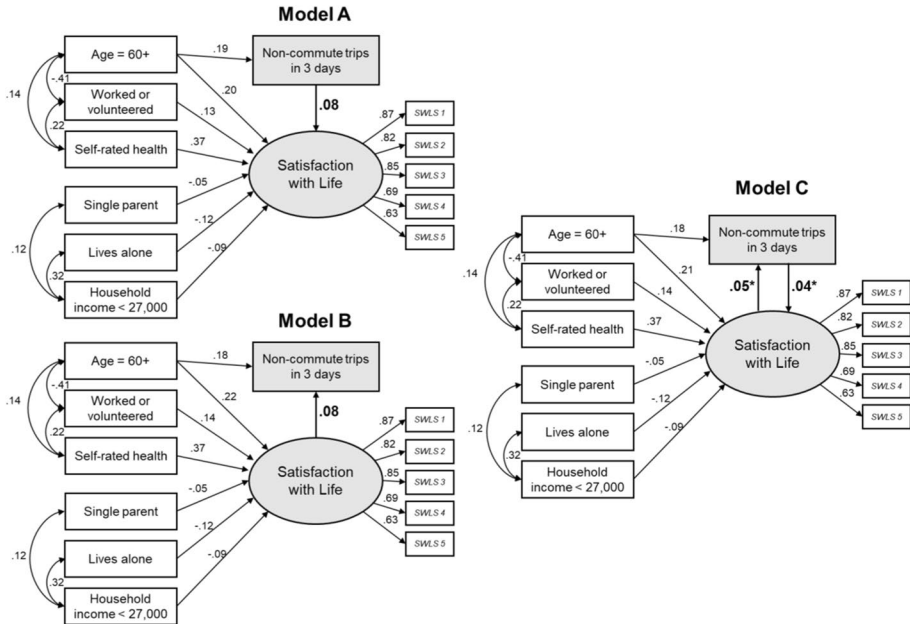
Fig. 2 Alternate structural equation model specifications. *Note* All coefficients are statistically significant, $p < .05$, except those indicated by an asterisk

was significantly associated with trip-making and that significant correlations occurred between many of the control variables (as shown in Fig. 2).

Figure 2 visually presents the results of three SEM models testing alternative relationships between trip-making and SWLS. Model A best matches the linear regression models in that it hypothesizes that non-commute trips influence life satisfaction. The regression weight between trip-making and SWLS was 0.08, similar and slightly higher than the weights found in the regression models (0.06 to 0.07). All of the control variables were significantly associated with SWLS (except gender which was excluded from the model). As with the regression models, the strongest predictors of SWLS were health, age, working status and living alone. The effect of non-commute trips was higher than being a single parent (-0.05) and on par with being in a low-income household (-0.09). Interestingly, being aged over 60 was associated with both higher life satisfaction and more non-commute trips.

Model B tested whether people who had a higher satisfaction with life were making more non-commute trips. Figure 2 suggests that this direction of causality is equally

significant (regression weight 0.08). The other relationships in the model were largely unchanged.

Model C included a reciprocal relationship, simultaneously modelling the impact of trips on life satisfaction and vice versa. Although the overall model is significant and largely unchanged, both coefficients measuring the reciprocal relationship are no longer significant when modelled together. This means we cannot conclude that one direction of causality is more significant than the other. Furthermore, it either means that the relationship between the two factors is not self-reinforcing, or the effect size is too small to be significantly detected given the sample size.

Discussion

This study is the first to empirically measure the association between the number of out-of-home trips and subjective well-being. It found a small but significant association between trips and well-being, regression coefficients ranging between .06 and .07. This effect was smaller than the association between well-being and health, income, age, employment status and living alone; however it was larger than the effect of being a single parent (.05). Commute trips did not have a significant relationship with well-being (see Model 2), suggesting that the effect is carried by non-commute trips.

Furthermore, we found no evidence that the relationship between mobility and well-being was non-linear. This runs counter to previous evidence of non-linear relationships between well-being and holiday-making or activity length (Kroesen and Handy 2014; Ravulaparthy et al. 2016), and the wider literature showing non-linear relationships between income and happiness (Kahneman and Deaton 2010).

The structural equation modelling showed that life satisfaction had just as strong an influence on mobility as mobility had on life satisfaction (coefficients were both 0.08). From this we cannot determine whether travelling more makes people happy, or whether happy people travel more.

We now continue the discussion by focusing on the linear relationship between the number of commute trips and subjective well-being. An important note is that this discussion is highly speculative, and testing these explanations is an important avenue for future research.

A possible explanation for finding a linear effect is that non-commute trips, which are often related to social activities (visiting friends, engaging in sports, etc.), may be speculated to increase well-being, at least within the observed range of trips made in our study. This is in contrast to increases in material conditions such as income, which will be more strongly affected by decreasing marginal returns. These diminishing marginal returns are caused, in part, because increasing income raises one's standards for what counts as high income, i.e. the hedonic treadmill effect (Brickman 1971). Furthermore, it may be that different non-commute trip types may demonstrate different effects on well-being; for example, social and leisure trips may have a linear effect whereas 'maintenance' trips (such as grocery shopping or appointments) may show a non-linear effect.

Related to this, it should be noted that the revealed linear effect is actually consistent with the finding that positive life satisfaction was just as likely to increase trip making as trip making was to increase life satisfaction. If happier people are more likely to travel than unhappy people, then perhaps people are 'self-selecting' the amount of non-commute travel that best suits their level of life satisfaction. Happiness and trip-making *may*

be self-reinforcing, creating a positive spiral over time, as predicted by the concept of the 'broaden and build theory' of positive psychology (Fredrickson 2004). Unfortunately, we were not able to establish these effects empirically as the non-recursive SEM was not statistically significant.

Countering the arguments above, it may be the case that the effect is actually non-linear, but that we were not able to establish this because the observations at higher numbers of trips were too few to provide reliable estimates (Fig. 1). Even though our sample was already quite large (N=1558) the confidence intervals for higher numbers of trips (>13) become rather broad. Of course, there is a natural ceiling effect here as well due to the constraints of travel time budgets (Ahmed and Stopher 2014). And it could be that the relationship becomes non-linear after a certain threshold value that is higher than the current number of trips that people make.

In closing, findings from this study raise many questions about the role of trip-making in improving individual well-being. If the direction of causality runs from happiness to trip-making, it suggests that people are able to self-select the amount of travel that supports their well-being (at least in this case study location). The relevance for policy would suggest that policy interventions to increase mobility will not result in greater life satisfaction, as long as there are enough options for people to self-select in areas where they can make the trips they want.

Moreover, it should be remembered that this study was undertaken in the Netherlands where destination accessibility is very high. Perhaps accessibility is a key mediating variable; it may be that the role of the transport system in facilitating well-being is much more crucial in cities or countries where the transport and land-use system are less accessible. And because happiness is related to trip-making only for non-commute trips, this is particularly relevant for destinations like shops, services, social and leisure opportunities. Increasing accessibility also increases the number of options available, which may increase well-being even if people do not make use of these options, as expressed in the concept of option value or motility (Geurs et al. 2006; Shliselberg and Givoni 2018). Further research into the role that accessibility plays in this relationship may help to clarify these complex relationships.

Finally, from a policy perspective, it seems relevant to further consider policies focused on people that would like to travel more, but for various reasons (e.g. low-income, old age, physical handicaps) are unable to do so. This study controlled for some of these factors, finding a significant relationship even when income, age and physical health were taken into account. However the study did not examine whether the relationship between transport and well-being differs among the socially excluded. Past research on social exclusion and transport disadvantage suggests that this is an important area for future research (Lucas 2012). Concretely, in addition to increasing accessibility levels in less-accessible areas, one could consider policies that provide assistance for transport disadvantaged. Conditional on the assumption that some people indeed travel less than they actually would like to (which would require additional research to investigate), the results of our analysis support such policies.

Authors' contribution AD research conception, research design, data analysis, results interpretation, lead paper writing, BW research design, results interpretation, paper writing, MK research design, results interpretation, paper writing, MH data analysis, paper writing

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Dr. Alexa Delbosc is a Senior Lecturer at the Monash Institute of Transport Studies in the Department of Civil Engineering. She is an Australian Research Council Discovery Early Career Researcher conducting a study of the changing travel behaviour of Australian millennials. She draws from her Master's in social psychology from Harvard University and PhD in Transport from Monash University to study the intersection between the transport system, individual travel and societal quality of life. She teaches Traffic Engineering and Management at Monash University with an emphasis on managing the system for the needs of all road users.

Maarten Kroesen is an Associate Professor at the Section of Transport and Logistics at Delft University of Technology, the Netherlands. His main research field is travel behavior research. He aims to contribute to this field by developing conceptual frameworks and related statistical models to analyze mobility panel data.

Bert van Wee is professor in Transport Policy at Delft University of Technology, the Netherlands, faculty Technology, Policy and Management. In addition he is scientific director of TRAIL research school.

Mathijs de Haas is a researcher at KiM Netherlands Institute for Transport Policy Analysis. His main area of interest is in studying dynamics in travel behavior using longitudinal data. He is also involved in the operation of the Netherlands Mobility Panel (MPN).