Latent growth curve trajectories for travel mode attitudes during and after the COVID-19 pandemic

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SHORT SUMMARY

This study models the growth trajectory of car and public transport attitudes, both as a function of age and the calendar year. Such growth analyses can improve our understanding of the changes in attitudes over time, information that could prove helpful for forecasting future travel-related attitudes and travel behaviour. For both the car and public transport, we find three latent classes with distinct growth trajectories. Public transport attitudes' growth follows a U-shape pattern as a function of age, minimising at around age 40. Car attitudes' growth trajectories follow an inverted U-shape, maximising around age 40. We find that the COVID-19 pandemic caused substantial changes in attitude values for both public transport and the car; with attitudes towards the former becoming more negative and towards the latter more positive. The magnitude of this change was related to the growth trajectory of the attitude, with a larger drop for the group that was already least favourable towards public transport. In the years since 2020, most attitudes have trended back towards the values seen before the pandemic. However, the more positive public transport groups' attitudes have not recovered yet.

Keywords: Attitudes; COVID-19; Latent Growth Curve Modeling; Travel Behaviour

1. INTRODUCTION

Since the re-introduction of travel-related attitudes to the field of travel behaviour research a quarter-century ago (Gärling et al., 1998), the study of attitudes has quickly regained traction. Attitudes are often defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour", following Eagly & Chaiken (1993, p.1). Within travel behaviour research we typically study attitudes pertaining to travel modes (car, bicycle, public transport) and attitudes relating to activity- or land-use patterns.

A distinction can be made between studies primarily interested in the travel-related attitudes themselves and studies primarily interested in establishing relationships between travel-related attitudes and other variables of interest, such as distance travelled using various travel modes. Within this second group, studies typically use travel-related attitudes as explanatory variables for travel behaviour. Examples can be found in the considerable literature on residential self-selection (Cao et al., 2009; Næss, 2009) or in many applications of hybrid choice models (Ben-Akiva et al., 2002; Vij & Walker, 2016). In the last decade, other relational studies have used panel data to test the direction of the relationship between travel-related attitudes and travel behaviour (Chorus & Kroesen, 2014; Kroesen & Chorus, 2018; Olde Kalter et al., 2021).

The first group of studies does not focus on relations between travel behaviour and attitudes but rather zooms in on the travel-related attitudes themselves. This type of study is comparatively less

common in the field of travel behaviour research. Examples discuss the different types of travel-related attitudes and the measurement of such attitudes (Bohte et al., 2009) as well as the differences in attitude values between various groups (Jensen et al., 2014; Zhou & Wang, 2019). This paper intends to further contribute to this research stream by explicitly accounting for the growth trajectory in travel-related attitudes over time: both as a function of a person's age and generation and as a function of the calendar year, resulting in a growth trajectory during and after the COVID-19 pandemic.

In other fields of study, such growth studies of attitudes are relatively common. A non-exhaustive list of examples includes attitudes towards education (Arens & Niepel, 2019; George, 2000), parenting (Han & Lee, 2018; Hartman et al., 2003) and gender roles (Cunningham, 2008; Katz-Wise et al., 2010). However, to the best of our knowledge, there are no such studies in the field of travel behaviour research. This study aims to fill this knowledge gap, intending to provide an understanding of the growth trajectory of travel-related attitudes. The conclusions that might be drawn from such growth studies could aid our understanding of travel-related attitudes, how they develop, and how they might change in the future. This information could potentially be used to inform travel behaviour forecasts.

The specific research objective of this paper is two-fold: first, we show how attitudes develop as a person ages, where we intend to separate the effects of age and those of cohort or generation. Second, we show the development of travel-related attitudes during and after the COVID-19 pandemic. Since we know that considerable heterogeneity exists with respect to both behavioural and attitudinal changes during COVID-19 (de Haas et al., 2020; Javadinasr et al., 2022), we explicitly account for this heterogeneity by estimating a latent class growth curve model. To achieve these contributions, we use nearly ten years' worth of panel data from the Netherlands Mobility Panel, spanning the years 2014 through 2022. In the remainder of this extended abstract, we further discuss our methods and data, followed by the results and discussion. Finally, we end with the main conclusions and our intended future extensions of the present work.

2. RESEARCH METHODS AND DATA

Research Method

Latent growth curve modeling is a method with its roots in psychology, aiming to understand how psychological concepts and processes evolve. Growth modeling in general quantify temporal patterns in longitudinal data. Note that the growth need not be positive: negative growth can be modelled as well. In the simplest form, such a method models the variable of interest as a function of an intercept (= the value at the start of the trajectory) and a slope (= the development over time), where the slope can made to be non-linear. At its root, this model assumes that all respondents' trajectories vary around the same model-estimated general trajectory. For an approachable introduction to growth modeling, the reader is referred to Curran et al. (2010).

Latent class growth analysis assumes that there are multiple distinct classes of individuals, with each class following a different developmental trajectory over time (Proust-Lima et al., 2012). A separate growth trajectory is estimated for each latent class. The latent class growth curve model can be extended with a class-membership model. The latent class growth curve or linear mixed models in this study are estimated using the statistical software package lcmm (Proust-Lima et al., 2017) for R (R Core Team, 2017).

Research Data

This study uses data from six waves collected using the Netherlands Mobility Panel (MPN), a longitudinal panel consisting of a 3-day travel diary and a set of questionnaires that has started in 2013 (for more information on the MPN, see Hoogendoorn-Lanser et al., 2015). In total, we used 5 038 distinct respondents and 22 289 responses, meaning that we collected an average of roughly 4.5 waves of data per respondent.

The main variables of interest in this study are travel mode attitudes. Attitudes are measured using six indicator statements for each mode. The public transport attitude combines the attitude statements relating to the train and those relating to bus, tram, and metro. Each indicator is scored on a 5-point Likert scale. The unidimensionality of these indicators is checked for each wave separately using principal axis factoring. The resulting yearly factor loadings are then averaged across the waves to ensure that the constructed scale is a consistent measurement over time. The final factor loadings are given in Table 1.

Table 1 Latent travel mode attitude indicators and factor loadings

	Car	Public Transport	
		Train	BTM
Travelling by (mode) is comfortable	0.845	0.758	0.812
Travelling by (mode) is relaxing	0.791	0.749	0.810
Travelling by (mode) saves me time	0.781	0.692	0.729
Travelling by (mode) is safe	0.778	0.467	0.553
Travelling by (mode) is flexible	0.796	0.742	0.767
Travelling by (mode) is satisfying	0.856	0.792	0.821

Nearly all factor loadings are above the desired threshold value of 0.7. The internal reliability of the scale was also found to be more than satisfactory.

Aside from the attitudes, we use a few other variables within the model presented in this extended abstract. First, we use the age of the respondent and the calendar year during the collected measurement to estimate the main growth trajectories. Assuming that there might be between-subject variation in growth trajectories that is explained by the respondents' gender and generation, these variables are used to inform the class-membership part of the model. Finally, we classify respondents as users of public transport or the car, based on the 3-day travel diary of 2018, and again use that information in the class-membership function.

3. RESULTS AND DISCUSSION

For both car- and public transport attitudes, we estimated models ranging from 1 to 4 latent classes. For both sets of attitudes, the four-class model performs statistically best as evaluated using both AIC and BIC. However, in both cases the fourth additional class consists of a very small subset of respondents (< 5%). For reasons of parsimony, we have therefore decided to use the 3-class model for both public transport and car attitudes.

The estimated parameters and class sizes for both models are given in Table 2. The growth models are visualized in Figure 1 and Figure 2, for public transport and the car respectively. These figures show the estimated growth based on both respondent age and calendar year for each latent class.

Table 2 Estimated parameters of latent class growth models for public transport and car attitudes.

	Public Transport (PT)			Car		
	Class 1 PT-sceptics	**Class 2** PT-enthusiasts	**Class 3** PT-doubters	**Class 1** Car-doubters	**Class 2** Majority	**Class 3** Car enthusiasts
N (persons)	5 038			5 038		
N (measurements)	22 289			22 289		
Nr. Of Parameters	29			29		
Log-likelihood	-17 744			-16 619		
AIC	35 546			33 295		
BIC	35 735			33 484		
Class Sizes (%)	15.6	22.1	62.3	10.0	51.7	38.3
Fixed effects in growth model						
Intercept (2014 + mean age)	2.18***	3.65***	2.97***	3.13***	3.88***	4.51***
Age (linear component)	0.0350***			-0.022***		
Age (square root component)	-0.441***			0.264***		
Years pre-pandemic	0.0202***			0.0220***		
Pandemic-drop (2020)	-0.430***	-0.128***	-0.214***	0.0782***	0.101***	0.117***
Years post-pandemic	0.0585***	-0.00932	0.0148*	-0.0862***	-0.0576***	-0.0470***
Fixed effects in class-membership model						
Delta	-1.04***	-0.744***		-0.102	0.682***	
Generation Ref: Generation X (1965 – 1980)						
Pre-WW2 (1900 – 1945)	-1.07***	0.241		0.228	0.382*	
Babyboom (1945 – 1964)	-0.667***	0.0727		0.0926	0.190*	
Millennials (1981 – 1996)	0.008	-0.179	Ref. class	-0.204	0.157	Ref. class
Gen Z (1997 – 2012)	-0.769***	-0395**		-1.367***	-0.162	
Gender, male (ref.: female)	0.205*	0.0578		-0.553***	-0.446***	
PT user 2018	-0.753***	0.987***		0.901***	0.396**	
Car user 2018	-0.0102	-0.641***		-1.66***	-0.473***	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

For public transport attitudes, there are three latent classes. The third class ('public transport doubters') is largest in size, with roughly 63% of respondents belonging to this class. The first and second class are substantially smaller, with roughly 16% and 22% of respondents belonging to each class respectively. Substantively, the third class's intercept (2.97), which represents the average attitude for this class in 2014, is roughly in-between that of the first class (2.18, lower) and second class (3.65, higher). Correspondingly, we named the first class the 'public transport sceptics', the second class the 'public transport enthusiasts', and the third class the 'public transport doubters'. In the years before the pandemic, public transport attitudes became slightly, but significantly, more favourable year-over-year (0.0201). There is a non-linear growth of public transport attitudes as age increases, with the relationship seemingly following a drawn-out U-

like pattern (see Figure 1). The minimum of the model-estimated growth curve is attained at the age of 43.

The drop due to the COVID-19 pandemic is negative across all three classes, indicating that the pandemic at least initially resulted in less favourable attitudes towards public transport. The magnitude of the drop varies across the classes and is related to the intercept value: the lower the attitude was before the pandemic, the more it dropped during the pandemic. For the latent class with the lowest mean public transport attitude and the corresponding largest drop in 2020 (class 1, the public transport sceptics), we do however see a relatively sharp recovery of the attitude in the years 2021 and 2022 of 0.0585 per year. This recovery is much smaller for the public transport doubters, with the median intercept value, and perhaps most worryingly even non-existent for public transport enthusiasts.

Turning our attention to the class-membership model, we find that both gender and generation have strong effects on class-membership probabilities. The two oldest generations (the pre-WW2 and babyboom-generations) are both less likely to belong to the public transport sceptics. The use of public transport and the car in 2018 is highly related to the class-membership, and thus to attitude growth trajectory. The causal direction of this effect is unclear: one could follow the normal interpretation of such class-membership covariates and argue that travel behaviour as recorded in 2018 affects which latent class people belong to, and thus explains part of the between-subject heterogeneity in attitude growth trajectory. If this is the case, then attitudes (and their trajectories) are affected by mode use, rather than the other way around. One could also argue for the opposite causal interpretation: people that belong to specific growth trajectories were more or less likely to have specific types of travel behaviours in 2018: people with less favourable public transport attitudes then were more likely to not use public transport, and the model picks up on this correlation. In our view, based on the general evidence supporting a bi-directional causal effect between attitudes and behaviour (De Vos, 2022), both arguments have merit. In either case, the model clearly establishes a strong link between attitude growth trajectory and travel behaviour.

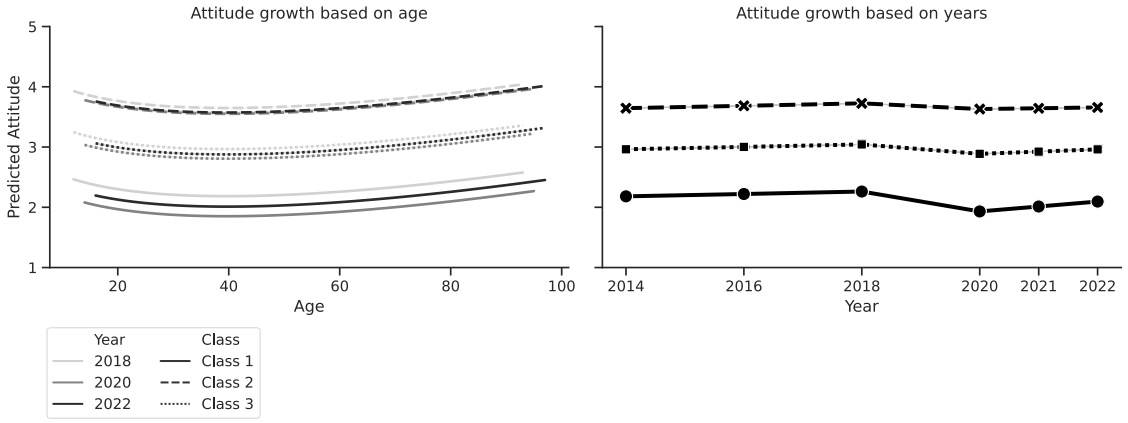

Figure 1 Overview of public transport attitude growth, both based on age and years

As for the attitudes towards the private car, we again find three latent classes with distinct growth trajectories, which are visualized in Figure 2. The second class is largest, and its intercept lies between the two other classes, which is why we named it the 'majority'. Slightly less than forty percent of respondents belong to the third class with the highest intercept value, correspondingly called the car enthusiasts, with only ten percent belonging to the first class of car doubters. From

these class sizes and the intercept values we can see that attitudes towards the car are generally more favourable and the class with a very high intercept value (4.51, car enthusiasts) is substantially larger than the public transport enthusiast class. Again, we find a non-linear growth trajectory as age increases, however, for the car the pattern follows an inverted U-shape. The maximum of this shape is attained at the age of 39, which is strikingly similar to the age where the minimum value towards public transport attitudes is attained (= 43).

For public transport, we found a negative effect of the pandemic. This is reversed for the car, where attitudes towards the car became more favourable in 2020 for all three latent classes. The effect was largest for the most positive group of car enthusiasts. In the years 2021 and 2022, as people became more accustomed to the changes brought by the pandemic, this trend reverted somewhat. For the least positive class (car doubters), this negative effect was even stronger than the initial positive change. This class thus has a less favourable attitude towards the car in 2022 than it had in 2018.

In the class-membership model we find significant effects of gender, as women are more likely to belong to the car doubters or the majority than men. The effects of generation are less pronounced compared to the public transport model. The most substantial effect is that of Generation Z, who are less likely to belong to the car doubters. As with the public transport model, we find very strong effects of public transport and car use in 2018 on the latent growth trajectories. Again, the causal direction of this effect is most likely to be bi-directional, but the model clearly shows a strong link between travel behaviour and car attitude growth trajectory.

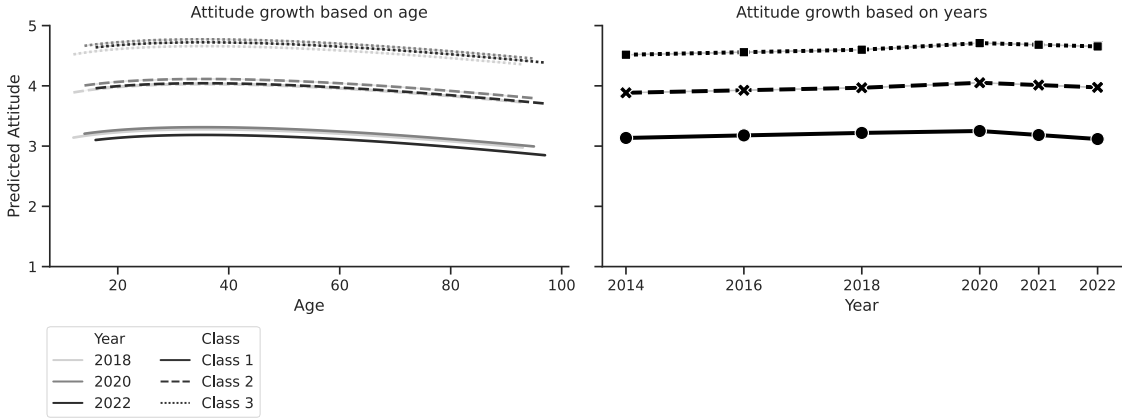

Figure 2 Overview of car attitude growth, both based on age and years

4. CONCLUSIONS

This study presented the results from two latent class growth models, studying the growth trajectory of attitudes towards public transport and the car. We set out to achieve two specific objectives: first, to determine how public transport and car attitudes grow over one's lifespan and separate the effects of generation and those of age and second, to model how these attitudes changed during and after the COVID-19 pandemic.

In relation to the first objective, our studies show that there is a non-linear growth trajectory of both public transport and car attitudes as a function of age. For public transport, this trajectory follows a U-like shape, with younger and older people being more positive and middle-aged people being more negative towards public transport. The lowest value for public transport was found to be attained around the age of 43. For the car, the trajectory follows an inverted U-shape with a

maximum value around age 39. We find significant effects of generation on the membership probability of the latent classes, indicating that people in different generations follow (slightly) different growth trajectories. For public transport, we find that older generations are less likely to belong to the latent class with the lowest public transport attitude. For the car, our model shows the reverse: generation Z (birthyear between 1997 and 2012) is less likely to belong to the class with the lowest attitude.

As for the second objective, our results show that public transport attitudes became less positive during 2020 whereas car attitudes became more positive. The drop in public transport attitudes was much larger for people who already had less favourable attitudes towards public transport. In 2021 and 2022 there is some recovery of the public transport attitudes. This recovery, however, is insufficient to compensate for the initial drop in 2020, and moreover, it is smaller or even non-existent for the two latent classes with more positive attitudes towards public transport. Car attitudes reverted to values seen before 2020 during 2021 and 2022. For the least positive group, the attitudes even became less favourable in 2022 than they were in 2018.

There are several next steps we intend to make in the near future. We intend to test different specifications to ensure the model properly separates age-effects from generation effects. We also want to further improve the relation with travel behaviour, ideally enabling us to test the direction of the effects within this growth modeling framework. Notwithstanding these future improvements, this study shows that growth modeling of travel-related attitudes provides new insights into the development of these attitudes and can aid the forecasting of future travel-related attitudes and thereby future travel behaviour.

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