A new perspective on the role of attitudes in explaining travel behavior: a psychological network model

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Attitudes have been used widely in models to explain variation in the travel behaviour. However, to model their influences on behavioural outcomes, two assumptions are typically made, which are not tenable conceptually nor empirically, namely the assumption that (1) attitudes - conceptualised as latent variables (LVs) - influence behaviour(s) and not vice versa and (2) items related to a certain attitudinal LV are independent conditional on the respective LV, typically referred to as the local independence assumption. Instead of assuming unidirectional causal paths between attitudes and behaviours and invoking the presence of LVs, researchers in psychology have therefore proposed to model the relationships between attitudinal and behavioural indicators as *undirected* networks. This research illustrates the potential new insights to be gained from the upcoming field of network psychometrics. In particular, a network model is estimated using data from a survey containing behavioural indicators regarding the use of public transport, the car and bicycle and six travel-related attitudes (for each mode). The results indicate that the extent to which the use of the mode is considered 'convenient' is most strongly connected to the actual use of the respective mode, and that the convenience of using the car takes a central position in the network.

1. Introduction

Attitudes, broadly defined as affective evaluations (favorable or unfavorable) with regard to particular objects or behaviors (Ajzen and Fishbein, 1977), are generally thought to play an important role in explaining (variations in) travel behaviour. Initial studies investigating the attitude-behavior relationship in a transportation context date back to the late 1970s (Dobson et al., 1978; Tardiff, 1977; Tischer and Phillips, 1979). Since then, more elaborate theoretical frameworks to study the effects of attitudes on behavior have been developed, the most prominent and influential being the Theory of Planned Behavior (Ajzen, 1991). This model has also been extensively applied in the transport domain (Bamberg, 2006; Bamberg et al., 2003). Over the past decade, it has also become popular to include attitudes in discrete choice models, leading to a class of so-called hybrid choice models (Ben-Akiva et al., 2002).

In travel behaviour research, attitudes are typically measured using multi-item scales. Such measurements may be subjected to an exploratory factor analysis to reveal underlying factors. Composite scores (factors scores or simply sum scores) can be used in a subsequent step to explain certain travel behaviour outcomes (e.g. the amount of travel by car). Alternatively, a pre-defined factor structure may be imposed on the data, i.e. a confirmatory factor model, which may then be simultaneously estimated along with a structural model detailing the relationships between the assumed subjective (attitudinal) factors and the travel behaviour(s) under investigation. In either case, it is assumed that the specific indicators to measure the attitudinal constructs are observed indicators of underlying Latent Variables (LVs), which can only be 'observed' indirectly.

The conceptualization outlined above rests on two crucial assumptions: (1) attitudes (conceptualised as LVs) influence behaviour(s) and not vice versa and (2) items related to a certain LV are independent conditional on the respective LV, typically referred to as the local independence assumption. This latter assumption reflects the idea that a LV represents the only cause underlying - and thereby the only source of co-variation among- the used set of observed indicators, which is an assumption that is generic to all reflective measurement models.

While these assumptions are crucial to statistical models in (psychologically-oriented) travel behavior research, they are typically not subject to either conceptual or empirical scrutiny. However, both from a conceptual and an empirical viewpoint, the assumptions are both problematic. Regarding the first assumption, bidirectional relationships can 'easily' be theoretically motivated based on cognitive consistency theories, i.e. inconsistencies between attitudes and behaviours may be resolved by either changing the behaviour *or* the attitude. Recent empirical studies (based on panel data) indicate that the relationship between attitudes and travel behaviour is indeed bidirectional; i.e. attitudes influence (later) behaviour, but behaviour also influences (later) attitudes.

The second (local independence) assumption is typically not reflection upon in travel behaviour research, but is increasingly under attack in general psychological research. Typically, residual associations between indicators remain after controlling for the LV, which likely originate from direct causal paths between the indicators. A compelling example relates to the construct of depression. Amongst others, typical items of scales to measure this construct consist of aspects such as 'insomnia', 'fatigue' and 'concentration problems'. It seems obvious here that, irrespective of a person's latent level of depression, there is a direct causal chain linking these 'symptoms', i.e. someone who sleeps poorly will be more fatigued and will likely experience concentration problems (Borsboom et al., 2013).

Instead of assuming unidirectional causal paths between attitudes and behaviours and/or invoking the presence of LVs, researchers have therefore proposed to model the relationships between attitudinal and behavioural indicators as *undirected* networks (Schmittmann et al., 2013), in which the observable items are represented as nodes and their interactions as edges. While directed networks (i.e. path models) are typically difficult to identify because equivalent models with different parameters may lead to equal model fit, undirected networks have the advantage that they are well identified (no equivalent models) and easily parameterized by using partial correlation coefficients. The underlying idea behind the use of partial correlations is that, while controlling for all other indicators in the network, these correlations provide the strongest evidence possible, i.e. when only cross-sectional data are available, of a causal effect between any two indicators (in either direction or both directions).

In this research we aim to introduce the upcoming field of *network psychometrics* to the field of travel behaviour research. In particular, to illustrate the potential new insights to be gained, we estimate a psychological network model using behavioural indicators regarding the use of public transport (PT), the car and bicycle and travel-related attitudes (six for each mode) as indicators of the network.

2. Data and measures

Data to estimate the network are obtained from a large representative sample of Dutch adults who completed a mobility survey in 2014 (N=1,376).[1] The sample distributions in terms of gender, age and education level are similar to the respective population distributions. In the following, the operationalisation of the travel behaviour and attitudinal indicators is discussed.

To assess people's travel behavior, the following open question was formulated: 'how many kilometers do you travel (approximately) in a regular week, using the following modes of transport?' Five modes were measured, but for the present analysis only the three most relevant modes in terms of distance travelled are considered: car as driver, bicycle and public transport (including bus, tram, metro or train). The distributions of distances travelled in a regular week are highly right-skewed and contained multiple extreme outliers. Since the strong deviations from normality would cause problems in the network model, we decided to recode the travel behavior variables into 5-point ordinal scales. With respect to car and bicycle use thresholds were chosen that divided the sample into more or less equal proportions. For public transport use this was not feasible since a large portion did not use this mode at all. For this mode, we therefore chose the same levels as for the car.

In line with Fishbein and Ajzen's (1977) recommendation to use the attitude towards the behavior as a predictor of behavior, we measured respondents' attitudes towards driving the car, cycling and using public transport. For each mode, following six items were measured:

1. [Driving by car / Cycling / Using PT] is easy
2. [Driving by car / Cycling / Using PT] is relaxing
3. [Driving by car / Cycling / Using PT] is fun
4. [Driving by car / Cycling / Using PT] is healthy
5. [Driving by car / Cycling / Using PT] is safe
6. [Driving by car / Cycling / Using PT] is environmental friendly

The network with 21 nodes (=3+3*6) is estimated using the EBIC graphical LASSO procedure (Foygel and Drton, 2010), a method to limit the number of spurious edges resulting in a sparse network. Since the data are all ordinal the estimation uses the polychoric correlations as input. Next, the resulting edge weight matrix can be used to visualise the network. This is done by the Fruchterman–Reingold algorithm that places nodes (indicators) with stronger and/or more connections closer together and the most central nodes into the center (Epskamp et al., 2018). Finally, to further aid interpretation of the network, several centrality measures are calculated, namely node strength, closeness and betweenness (Opsahl et al., 2010).

3. Results

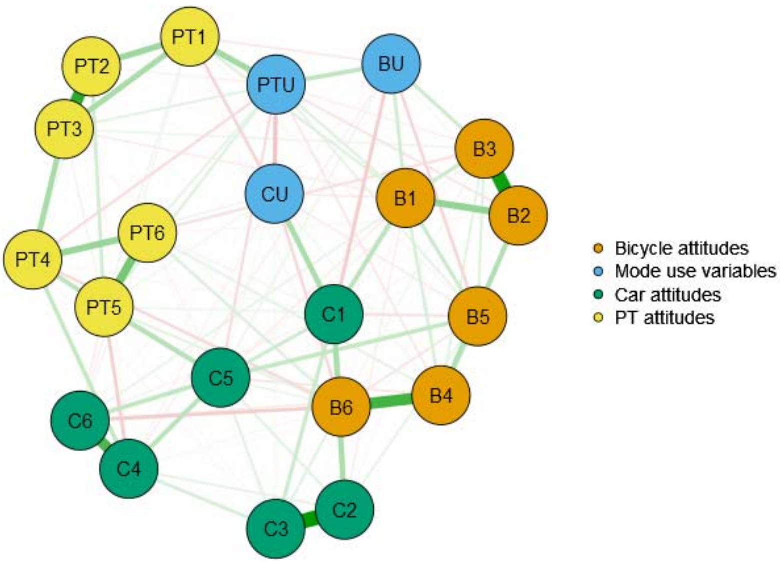
Using a tuning parameter of 0.5, 154 out of 210 possible edges (between the 21 nodes) were found to be nonzero. The network (Figure 1) clearly shows the existence of three clusters reflecting the attitudes towards each of the three modes. The mode use variables form a separate (fourth) cluster. Interestingly, for each mode, the attitude reflecting the extent to which the use of the mode is considered 'convenient' is most strongly connected to the actual use of the respective mode. Convenience, in turn, is most strongly linked with the degrees the use of the mode is considered 'fun' and 'relaxing'. For each of the three modes, the perceptions of safety, healthiness and environmental

[1] The used data are freely available to academic researchers (http://www.lissdata.nl/).

friendliness also form (sub)clusters, which take a more distant position in relation to the actual use of each mode, suggesting that these are secondary reasons for mode use.

In line with the network visualization, the centrality indices (Figure 2) indicate that the perceived convenience of using the car takes a central position in the network. Interestingly, this attitude is positively connected with the perceived environmentally friendliness associated with bicycle use, an attitude which also takes a central position in the network. Hence, whereas attitudes regarding the environmental friendliness of car and bicycle use (C6 and B6) are negatively correlated (as can be expected), the attitudes 'car is convenient' (C1) and 'cycling is environmental friendly' (B6) actually positively reinforce each other. It may be speculated that such linking of positive benefits related to different aspects of each mode, is actually a (unconscious) strategy of the human mind to avoid serious dissonance among the attitudes associated with the three modes.

Overall, by relaxing two problematic assumptions of travel behaviour research ((1) attitudes influence behaviour and not vice-versa and (2) items are independent conditional on the LV) the psychological network approach offers a new and refreshing perspective on how attitudes and behaviours interrelate and potentially 'cause' each other. Moreover, given the methodological and mathematical focus of transportation researchers, we believe the field of transport modelling is ideally positioned to contribute to and further develop the field of network psychometrics.



CU	Car use
C1	Driving by car is convenient
C2	Driving by car is relaxing
C3	Driving by car is fun
C4	Driving by car is healthy
C5	Driving by car is safe
C6	Driving by car is environmental friendly
BU	Bicycle Use
B1	Cycling is convenient
B2	Cycling is relaxing
B3	Cycling is fun
B4	Cycling is healthy
B5	Cycling is safe
B6	Cycling is environmental friendly
PTU	PT use
PT1	Using PT is convenient
PT2	Using PT is relaxing
PT3	Using PT is fun
PT4	Using PT is healthy
PT5	Using PT is safe
PT6	Using PT is environmental friendly

Figure 1. Network visualization

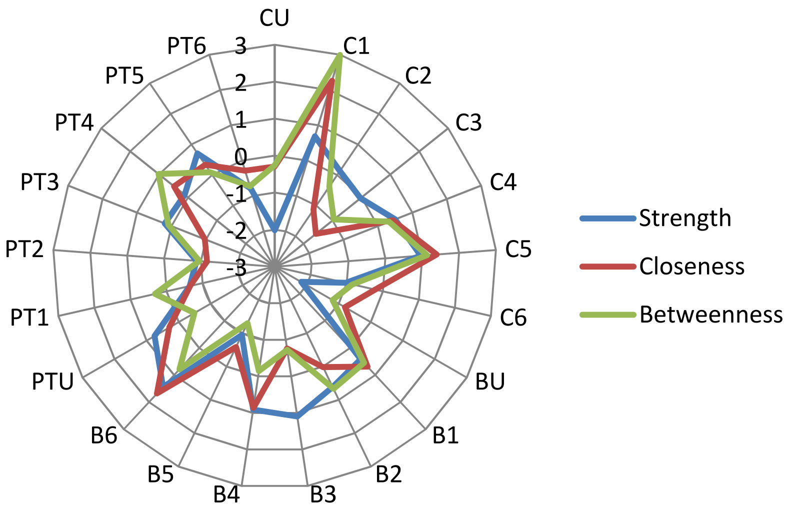


Figure 2. The centrality of each node in terms of strength, closeness and betweenness (expressed in standardized scores)

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